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NOISE COMPARISON OF TWO 1.2-PRESSURE-RATIO FANS WITH 15 AND 42 ROTOR BLADES

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16. Abstract

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SUMMARY

In this report, two 1.829-meter- (6-ft-) diameter fans suitable for a quiet engine for future short-takeoff-and-landing (STOL) aircraft were compared. Both fans were designed for a 1.2 pressure ratio with similar weight flows, thrusts, and tip speeds. The first fan, designated QF-9, had 15 rotor blades and 11 stator blades. The rotor was highly loaded and the tip solidity was less than 1. The QF-9 rotor blades had an adjustable-pitch feature which can be used for thrust reversal. The second fan, designated QF-6, operated at a moderate loading with a rotor tip solidity greater than 1. Fan QF-6 had 42 rotor blades and 50 stator blades. The low number of rotor blades for QF-9 reduced the frequency of the blade-passage tone below the range of maximum annoyance. In addition to this difference, the QF-9 fan had a somewhat smaller rotor-stator separation than the QF-6 fan.

In terms of sound pressure level and sound power level, QF-9 was the noisier fan, with the power level results for QF-9 being about 1 decibel above those for QF-6 at equivalent operating points as determined by similar stage pressure ratios. At these same equivalent operating points, the maximum perceived noise along a 152.5-meter (500-ft) sideline for QF-9 was about 2.5 PNdB below that for QF-6, which indicated that QF-9 was less objectionable to human hearing.

INTRODUCTION

Short-takeoff-and-landing (STOL) aircraft of the future are planned for operation near highly populated areas. The reduction of engine noise is therefore a very important consideration that will largely dictate the engine design. In this report, two candidate 1.829-meter- (6-ft-) diameter, low-tip-speed fans for a low-noise engine are compared. One fan, designated QF-9, features an unusually low number of rotor and

stator blades with high rotor blade loading. In addition, the QF-9 rotor blades have an adjustable-pitch feature which provides an unconventional method of thrust reversal for fans. The second fan in this comparison, designated QF-6, is a fixed-pitch fan that has a higher number of blades with moderate loading.

The low number of rotor blades on QF-9 was expected to yield a noise benefit in reducing the frequency of the blade-passage tone relative to that of QF-6, since the shaft rotation speeds were about the same. If it is assumed that the level of the tone is unchanged, the tone at low frequency is less annoying than a high-frequency tone. This result would be reflected in a lower calculated perceived noise level. This study compares the two fans in terms of sound pressure level, directionality, and perceived noise.

APPARATUS

Fan Assemblies

The acoustic and aerodynamic data in this report are for the design nozzle configurations. Fan QF-6 was designed by NASA; fan QF-9 was a contractor design. The specific design approaches differed for the two fans. In table I, selected design configuration parameters are compared for the two fans. In addition to a 1.2 pressure ratio, both fans were designed for approximately the same weight flow, thrust, and tip speed. Fan QF-9 is much more highly loaded than QF-6 as shown by the D-factor, which has a maximum of 0.530 for the QF-9 rotor compared to a maximum of 0.386 for the QF-6 rotor. The D-factor remains at a high level over the entire length of the QF-9 rotor. The QF-9 rotor and stator chords are considerably longer than those of QF-6. Fan QF-9 was designed by Hamilton-Standard.

Figures 1 and 2 show the blading of the conventional fan, QF-6. In figure 1, the view of the partially assembled stage shows the 42 fixed-pitch blades of the rotor. Figure 2 shows part of the 50-blade stator assembly.

Figures 3 and 4 show the blading of QF-9. Figure 3 shows part of the 15-blade rotor assembly. The chord of these blades increases from hub to tip, with a maximum value of 34.3 centimeters (13.5 in.) at the tip. These blades have an adjustable-pitch feature, although for this comparison the rotor blades remained at the design setting. The partially assembled QF-9 stator, shown in figure 4, clearly shows the very-low-solidity, large-chord blading. The adjustable-pitch feature of QF-9 was not feasible for QF-6 because of mechanical complexities required to actuate such a large number of blades.

Figure 5 presents the relative positions of the QF-6 and QF-9 blading as viewed looking toward the fan axis from the blade tips. To reduce rotor-stator wake inter-

action, a major noise-generating mechanism, it is desirable to increase the axial spacing between these blade rows. For QF-6, the spacing is about four rotor-chord lengths. However, the large-chord blades limited the practical spacing for QF-9 in the facility to about two rotor-chord lengths at the tip. The large camber of the QF-9 blades resulted primarily from the lower solidity levels for that design (table I(b)). Differences in blade camber and chord angle are more pronounced for the stator blade because of large differences in design incidence angle for the two designs.

Figure 6 is a cutaway sketch of a typical fan installation as tested at the NASA Quiet Fan Facility. The sketch is a schematic representation showing the drive shaft in the fan inlet and the support pylon. In all testing, the fan flow passage was completely hard, that is, with no acoustic suppression treatment.

Facility

The fans compared in this report were tested at the NASA Quiet Fan Facility, shown in figure 7. The fans are located on a concrete pedestal 37 meters (121 ft) from the face of the wind tunnel drive motor building. The wind tunnel drive motors are used to drive the fan through a gearbox and drive shaft. The acoustic data were taken with an array of microphones located at the fan centerline elevation on a 30.5-meter (100-ft) radius from the fan at 10° increments from 10° to 160° from the fan inlet centerline. Data were not taken at 0° because of the presence of the drive shaft, nor above 160° because of high-velocity fan exhaust. In figure 7, the microphones are shown covered with plastic bags as weather protection. Foam treatment is shown on the portion of the drive motor building wall that was considered likely to cause a sound reflection problem at the microphone locations. Figure 8 is a sketch of the test site. The entire test site surface was hard asphalt.

Instrumentation

Both fans had several similar measuring stations to allow a measurement of the fan aerodynamic performance. Figures 9 and 10 show the axial locations of the measurement stations on QF-6 and QF-9, respectively. Figure 11 shows the detailed layout of this instrumentation at each of the four measuring stations. Six equally spaced thermocouples were located on the lip of the bell-mouthed inlet to determine the average inlet temperature. Six static taps were located in the outer wall of the inlet duct. These static taps were used for the inlet weight flow calculation. Four identical total pressure and temperature rakes were used downstream of the stator blade row to determine the stage weight flow and the stage total pressure ratio. These rakes were located nominally

at 90° intervals but were displaced slightly in order to avoid being in a stator wake. Finally, just downstream of the nozzle exit, three equally spaced total pressure rakes were used for thrust measurements. These three rakes were arranged as shown to avoid the wake from the support pylon. All rakes were removed for acoustic tests.

PROCEDURE AND DATA REDUCTION

The aerodynamic data were recorded through a pressure multiplexing valve, a pressure transducer, and a computer network. This system recorded nine samples in about 90 seconds. These raw data samples were averaged and used to compute the desired flow parameters.

Three separate 100-second samples for each speed point were recorded from the microphone data on magnetic tape for later analysis. Simultaneously with the magnetic tape recording, an on-line one-third-octave-band analyzer was used for 4 seconds on each microphone sample, and the results were recorded on digital tape. These one-third-octave digital data were further adjusted for atmospheric absorption to obtain results corrected to standard-day conditions of 15° C and 70 percent relative humidity. The data were not adjusted for ground reflection. From these standard-day, sound pressure level data, the sound power level and perceived noise values were calculated. For the perceived noise level determinations, the data were adjusted to a 152.5-meter (500-ft) sideline, which has become standard practice for STOL noise evaluations. A more detailed discussion of the acoustic data analysis for the Quiet Fan tests is given in reference 1.

RESULTS AND DISCUSSION

Aerodynamic Performance

At a given percent of design speed, the total pressure ratio of the QF-6 fan was slightly higher than that of the QF-9 fan. The design inlet weight flow of 396 kilograms per second (873 lbm/sec) was achieved with QF-6, but a stage pressure ratio of only 1.182 was obtained rather than the design-predicted 1.2. The measured thrust of QF-6 was 59 575 newtons (13 393 lbf), which is below the design value of 70 415 newtons (15 830 lbf). As shown in table II, the performance of QF-9 also fell somewhat short of the design-predicted values of weight flow and pressure ratio. The measured weight flow was 388 kilograms per second (855 lbm/sec), as compared to the predicted 403 kilograms per second (889 lbm/sec); the measured thrust was 56 412 newtons (12 682 lbf), as compared to the predicted 71 705 newtons (16 120 lbf); and the pressure

ratio at design speed was 1.170. Throughout this report, the fan-stage total pressure ratio is used, as well as the percent of design speed, as a means of correlating the acoustic data of the two fans. To achieve a higher pressure ratio, QF-9 was run at speeds above its design speed.

Perceived Noise Directionality

Figure 12 is a series of five plots which compare overall perceived noise level (PNL) as a function of angle on a 152.5-meter (500-ft) sideline for the two fans at various speeds. In each plot, the two-lobe nature of the noise is evident, with both fans being rear-quadrant dominated. Figure 12(a) compares the two fans at 60 percent of their design speeds. At all angles except 10^{o} along the sideline, QF-6 has the higher perceived noise level, with the difference being especially marked in the rear quadrant. At 60 percent of design speed, the pressure ratio of QF-6 is slightly above that of QF-9.

At 70 percent of design speed, figure 12(b), both fans produce about the same PNL's in the front quadrant, with QF-6 again dominating the rear quadrant. Again, QF-6 has the slightly higher stage pressure ratio.

QF-9 was run at 86 and 93 percent of design speed rather than at the 80- and 90-percent speed points of QF-6, which had been run earlier. Eighty-six percent of design speed was specified by the fan-stage designer as the approach speed, with 93 percent of design speed being selected as an additional point between the approach and 100-percent (takeoff) speed. In figure 12(c), the results for QF-6 at 80 percent of design speed are compared with those for QF-9 at the existing 70- and 86-percent speeds. In the front quadrant, QF-6 at 80-percent speed has only a slightly higher PNL than QF-9 at 70-percent speed. In the rear quadrant, the results of QF-6 compare very closely with the results of QF-9 at 86-percent speed; although the QF-9 pressure ratio is higher, 1.125 compared to 1.080 for QF-6.

At 90 percent of design speed, figure 12(d), the QF-6 results compare closely in PLN level with the results of QF-9 at the existing 86- and 93-percent speed at the front angles. In the rear quadrant, the noise of QF-6 dominates both QF-9 cases.

Finally, in figure 12(e), the results of QF-6 at 100 percent of design speed are compared with the results of QF-9 at both design speed and 110 percent of design speed, where the QF-9 pressure ratio is 1.210 - slightly above its predicted design value. At 100-percent speed, QF-6 is still the noisier fan at all angles.

Sound Pressure Spectra

The low number of rotor blades in the QF-9 design was expected to lower the QF-9

blade-passage-tone frequency (BPF) to a region of less sensitive human hearing. The sound pressure level spectra show the frequencies of the fan's blade-passage tones. The one-third-octave sound pressure level (SPL) spectra corresponding to the peak angular overall sound pressure levels (OASPL) are compared in figure 13 for the front quadrant and in figure 14 for the rear quadrant. Comparisons are made in the same manner with respect to speeds as were the PNL distributions of figure 12. In figures 13 and 14, however, the data are for the 30.5-meter (100-ft) microphone radius rather than a 152.5-meter (500-ft) sideline.

Front quadrant. - The blade-passage-tone spikes (BPF) and the first overtone, or second harmonic (2H), are designated for each spectrum. In some cases, a shift in fan speed is not enough to place the blade-passage tone in a different one-third-octave filter. Hence, the tone SPL appears to be at the same frequency for two speeds. Figure 13 presents the SPL spectra at the angle of maximum OASPL in the front quadrant; figure 14 presents the SPL spectra at the angle of maximum OASPL in the rear quadrant. In each comparison, the blade-passage tone for QF-9 is clearly at a much lower frequency than for QF-6 because of the fewer number of rotor blades.

The front-quadrant spectra at 60 and 70 percent of design speed are shown in figures 13(a) and (b); the QF-9 SPL is above the QF-6 SPL from 200 hertz to about 1000 hertz and below the QF-6 SPL at higher frequencies. Also, the level of the blade-passage-tone spike is higher for QF-9 than for QF-6 at these two speeds.

Figure 13(c) compares the SPL spectrum for QF-6 at 80 percent of design speed with the spectra for QF-9 at 70 and 86 percent of design speed. It is noteworthy that the blade-passage-tone spike is at a much higher SPL for both QF-9 cases than for QF-6, even though the QF-9 pressure ratio at 70-percent speed is only 1.081, compared to the QF-6 80-percent-speed value of 1.117. QF-6 has a higher SPL at all frequencies above 1200 hertz.

Figure 13(d), comparing the results of QF-6 at 90-percent speed with the results of QF-9 at 86 and 93 percent of design speed, shows the same high relative levels for the QF-9 blade-passage tones. Otherwise, in figure 13(d), QF-9 is seen to be the dominant noise source to about 1600 hertz, with QF-6 being the noisier fan above this frequency.

Finally, figure 13(e) compares the SPL spectrum for QF-6 at design speed with the design-speed and 110-percent-speed spectra of QF-9. The QF-9 levels continue to dominate to about 1600 hertz. Above 1600 hertz, the noise of QF-6 has the higher SPL. There is little difference between the two QF-9 spectra at frequencies above 1600 hertz.

In general, the QF-9 sound pressure levels are higher than the QF-6 levels at low frequencies, to about 1000 hertz, with QF-6 having the higher levels at the higher frequencies. These differences in SPL are caused by the relative locations of the blade-passage tones for the two fans. In addition, the internal broadband noise which is relatable to the blade chord lengths (ref. 2) is expected to be lower in frequency for QF-9 than for QF-6 because of the larger rotor-chord lengths of QF-9.

Rear quadrant. - Figure 14 presents the same type of comparison for the rear quadrant that figure 13 presents for the front quadrant. In the front quadrant, figure 13, QF-9 typically has a higher blade-passage SPL level than QF-6. In the rear quadrant, the blade-passage spikes are at nearly the same levels.

Beginning with the 60-percent-speed comparison of figure 14(a), the QF-9 results as usual dominate to about 1000 hertz; the results of QF-6 dominate above this frequency. The blade-passage-tone SPL for QF-6 is slightly higher than that for QF-9.

At 70-percent speed, figure 14(b), the blade-passage tone SPL's have nearly the same level for QF-6 and QF-9.

Figure 14(c) compares the results of QF-6 at 80-percent speed with the results of QF-9 at 70- and 86-percent speed. Here the level of the blade-passage tone of QF-6 falls between the levels for the QF-9 blade-passage tones at 70- and 86-percent speed. The QF-6 SPL is above both QF-9 cases at frequencies above 1600 hertz, although there is a marked increase in the higher frequency SPL of QF-9 as its speed is increased from 70 to 86 percent.

In figure 14(d), comparing data for QF-6 at 90-percent speed with the data for QF-9 at 86- and 93-percent speed shows that the blade-passage-tone SPL's are nearly the same.

Finally, in figure 14(e), comparing the SPL for QF-6 at design speed with the SPL for QF-9 at design and 110-percent speed shows that the QF-9 SPL is much greater than the QF-6 SPL at the lower frequencies ($<$1600 Hz). Only in the 110-percent-speed case does the QF-9 blade-passage-tone SPL slightly exceed the blade-passage-tone SPL for QF-6. In this case, QF-9 has a pressure ratio of 1.210 compared to 1.182 for QF-6. At the higher frequencies, QF-9 at 110-percent speed nearly matches the SPL of QF-6.

Thus, the maximum rear-quadrant noise data of figure 14 show that the BPF tones for the two fans are about equal and that the broadband noise of QF-9 is greater than that of QF-6 at all frequencies to the QF-6 BPF. At all higher frequencies, the QF-6 broadband is higher except for at 110-percent speed, where the level of QF-9 is about equal to that of QF-6 at 100-percent speed.

Narrow-Band Spectra

The front- and rear-quadrant tape-recorded data were also analyzed with a constant 32-hertz-bandwidth narrow-band analyzer and are presented in figure 15. These detailed spectra show the blade-passage tones (designated BPF) and the associated harmonics much more clearly than did the one-third-octave analysis. The data presented in figure 15 were not corrected for standard-day conditions. The measurements were taken at a 30.5-meter (100-ft) radius from the fan. In figure 15(a), the results of QF-6 and QF-9 at design speed are compared at 20°, as a typical angle. As in the one-third-

octave front-quadrant spectra of figure 13, the blade-passage-tone SPL of QF-9 is above that of QF-6. At frequencies above the QF-6 BPF, the broadband noise of QF-6 has the higher level, reaching an almost constant 4 decibels higher than the QF-9 SPL above 4000 hertz. Figure 15(b) compares the results of QF-6 at design speed and QF-9 at 110-percent speed at 20°. At this front-quadrant position, the QF-9 SPL's at 110-percent speed are very nearly the same as the QF-9 SPL's observed at design speed (fig. 15(a)), except for the blade-passage-tone level, which is slightly higher at the 110-percent speed. These same comparisons are made at a typical rear-quadrant angle, 130°, in figures 15(c) and (d). Figure 15(c) compares the design-speed spectra for the two fans. At this rear-quadrant position, the QF-6 SPL assumes an almost constant 7-decibel increase over the corresponding QF-9 design-speed SPL above 4000 hertz. Finally, in figure 15(d), the QF-9 110-percent-speed SPL results are at about the same levels as the QF-6 design-speed results at frequencies above 4000 hertz. Note that in the rear quadrant (at 130°) the QF-9 110-percent-speed SPL levels are above the QF-9 design-sped SPL's, while in the front quadrant (at 20°) increasing the QF-9 speed from design to 110 percent had little effect on the sound pressure levels.

Power Level Spectra

The sound power level (PWL) spectra, integrated from 10° to 160°, are presented in figure 16. The comparison at 60-percent speed, figure 16(a), shows the blade-passage tones for both fans at the same power level. Otherwise, as noted for the SPL's, QF-9 has the higher sound power level below 1000 hertz and QF-6 has the higher level at the higher frequencies. At 70 percent of design speed, figure 16(b), the QF-9 blade-passage tone is now above the level of the QF-6 tone. In figure 16(c) with QF-6 at 80-percent speed and QF-9 at 70- and 86-percent speed, the results of QF-6 still dominate above 2000 hertz. The QF-9, 70-percent-speed-spectrum, blade-passage-tone PWL is about the same as that for QF-6; the tone PWL for the 86-percent-speed spectrum is considerably above the QF-6 level. Figure 16(d) compares the 90-percent-speed spectrum of QF-6 with the 86- and 93-percent-speed spectra of QF-9; again QF-9 clearly dominates the lower frequencies, and QF-6 the higher frequencies. The QF-9 blade-passage-tone PWL at both speeds is above the QF-6 level. Finally, at the design speed for QF-6 and both design speed and 110-percent speed for QF-9, figure 16(e), the QF-9 results still dominate the low-frequency PWL spectra. At higher frequencies, QF-6 is still the noisier fan, but the difference between QF-6 and QF-9 is less than at the lower speeds. At design speeds, the QF-6 blade-passage-tone PWL is slightly greater than the QF-9 value. However, the blade-passage-tone PWL of QF-9 at 110-percent speed is well above that of QF-6 at design speed.

The appendix introduces computer tabulation and plots of the acoustic data. These tables and plots can be found at the end of this report.

Overall Correlations

Throughout this report, the percent of design speed and the stage pressure ratio have been used to identify the sound data test points. Figure 17 relates the overall sound power level (OAPWL) to the percent of design speed for both fans. In this comparison, both fans seem to have about the same OAPWL at any given speed from 60 percent to design speed. The slope of the QF-9 OAPWL curve has an inflection before the increase to the overspeed points.

Perhaps a more meaningful way to correlate these data, considering the actual stage performance, is to plot the OAPWL against the stage pressure ratio. This is done in figure 18. Now QF-9 is seen to produce a slightly higher OAPWL (about 1 dB higher) for a given pressure ratio to the design-speed point of 1.170 pressure ratio. This higher OAPWL might have been caused by the higher loading levels and closer rotor-stator spacing of QF-9 compared to QF-6. Again, the overspeed data show a continued increase in OAPWL.

The maximum perceived noise levels along a 152.5-meter (500-ft) sideline are plotted as a function of the percent of fan design speed in figure 19 and as a function of the stage pressure ratio in figure 20. In figure 19, the maximum sideline PNL is about 2.5 PNdB lower for QF-9 than for QF-6 at similar fan speeds. When this maximum sideline PNL is plotted as a function of the stage pressure ratio, as in figure 20, QF-6 still has the higher noise level. However, the PNdB difference between the two fans is not as great as in the comparison of figure 19. Thus, the use of the small number of blades in QF-9 did achieve a small measure of perceived noise relief by shifting the noise to a lower frequency range, a region of lower human ear sensitivity.

CONCLUDING REMARKS

Two candidate fans (QF-9 and QF-6) for a quiet, short-takeoff-and-landing (STOL) aircraft were compared for acoustic performance. Fan QF-9 is a highly loaded design, with a solidity less than 1, that uses a low number of rotor and stator blades. The very low number of rotor blades (15) lowers the blade-passage frequency and allows QF-9 to have an adjustable-rotor-pitch feature which can be used for thrust reversal. The second fan in the comparison, QF-6, has a high solidity and moderate loading with a higher number of rotor (42) and stator blades. Both fans were designed for a 1.2 stage pressure ratio and similar tip speeds and weight flows.

Neither fan achieved the design stage pressure ratio; QF-6 came closer, with a pressure ratio of 1.182 compared to 1.170 for QF-9. Fan QF-6 achieved its design inlet weight flow at design speed, but QF-9's measured weight flow at design speed was slightly below the predicted value.

The sound pressure level and sound power level spectra for QF-6 and QF-9 at similar stage pressure ratios and fan speeds show QF-9 to be consistently noisier at the lower frequencies ($\lesssim$1000 Hz), depending on the fan speed. Fan QF-6 is noisier at the higher frequencies.

In the front quadrant, the blade-passage-frequency sound pressure level was consistently higher for QF-9 than for QF-6; in the rear quadrant, the tones were very nearly at the same level for the two fans. Both fans had higher perceived noise levels in the rear quadrant than in the front quadrant at all speeds. As a function of percent of fan design speed, both fans produced about equal overall sound power levels. However, because of the somewhat lower pressure ratios of QF-9 as a function of speed, QF-9 has a somewhat higher overall sound pressure level than QF-6 at a given pressure ratio.

The main acoustic result of the reduced number of blades on QF-9 was to lower its major noise contribution, the blade-passage tone, to lower frequencies where it is less objectionable to human hearing. In terms of preceived noise levels, QF-9 was less objectionable than QF-6, especially in the rear quadrant.

The low-blade-number approach used in the QF-9 design shows promise as a method of reducing the perceived noise level of a quiet STOL engine. Also, the variable-pitch feature, made practical by the low number of blades in QF-9, could be a considerable asset in a future quiet STOL engine.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, June 25, 1973,
501-24.

APPENDIX - COMPUTER TABULATION AND PLOTS OF ACOUSTIC DATA

This appendix introduces computer listings and plots of the acoustic data for QF-6 and QF-9. Figure 21 presents the sound power level (PWL) spectra for QF-6 and QF-9. Figure 21(a) presents the PWL spectra for QF-6 at 60, 70, 80, 90, and 100 percent of design speed. Figure 21(b) presents the PWL spectra for QF-9 at 60, 70, 86, and 93 percent of design speed. Figure 21(c) presents the PWL spectra for QF-9 at 100, 110, 115, and 120 percent of design speed.

Figures 22(a), (b), and (c) present the corresponding overall sound pressure level distribution on a 30.5-meter (100-ft) radius for QF-6 and QF-9.

Figures 23(a), (b), and (c) present the corresponding perceived noise on a 30.5-meter radius for QF-6 and QF-9.

Figures 24, 25, and 26 present the one-third-octave sound pressure level spectra at each angle from 10° to 160° from the fan inlet.

Table III is a listing of the acoustic data for QF-6.

Table IV is a listing of the acoustic data for QF-9.

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TABLE I. - FAN DESIGN CHARACTERISTICS

(a) Aerodynamic design parameters

Parameter	QF-6	QF-9
Overall total pressure ratio	1.20	1.20
Rotor-stator separation, number of rotor chords	4.0	~2.0
Predicted overall efficiency, percent	87.9	90.2
Corrected inlet weight flow, kg/sec (lbm/sec)	396 (873)	403 (889)
Corrected inlet specific weight flow, kg/(sec)(m^2) (lbm/(sec)(ft^2))	181.6 (37.4)	194.8 (39.9)
Thrust, N (lbf)	70 415 (15 830)	71 705 (16 120)
Work coefficient	0.338	0.369
Rotor head-rise coefficient	0.311	0.348
Stage head-rise coefficient	0.298	0.334
Corrected rotor tip speed, m/sec (ft/sec)	229 (750)	213 (700)
Tip diameter, m (ft)	1.829 (6.0)	1.829 (6.0)

(b) Blade design parameters

Parameter	QF-6		QF-9	
	Rotor	Stator	Rotor	Stator
Number of blades	42	50	15	11
Chord, cm (in.):				
Hub	17.5 (6.89)	11.7 (4.61)	21.5 (8.46)	38.1 (15.0)
Tip	16.3 (6.40)	11.7 (4.61)	34.3 (13.5)	38.1 (15.0)
Solidity:				
Hub	2.827	1.752	1.219	1.406
Tip	1.188	1.000	0.893	0.714
D-factor:				
Hub	0.151	0.417	0.530	0.512
Maximum	0.386	0.417	0.530	0.512
Tip	0.357	0.301	0.431	0.363
Cruise design corrected speed, rpm	2387.2	----------	2227.0	----------
Rotor blade-passage frequency, Hz	1671	----------	557	----------
Camber angle, deg:				
Hub	36.15	34.11	44.89	52.50
Tip	8.98	15.83	18.40	56.40
Chord angle relative to fan axis, deg:				
Hub	6.12	10.77	5.61	16.30
Tip	43.04	2.07	41.14	11.92
Aspect ratio, mean	3.08	3.46	1.70	1.23
Rotor inlet hub-tip radius ratio	0.416	----------	0.460	----------
Tip relative inlet Mach number	0.878	----------	0.865	----------
Material	Aluminum	Aluminum	Plastic/ titanium	Aluminum

TABLE II. - SELECTED AERODYNAMIC PARAMETERS AT DESIGN SPEED - DESIGN PREDICTION COMPARED WITH MEASURED RESULT

Parameter	QF-6	QF-9
Design corrected tip speed, m/sec (ft/sec)	229 (750)	213 (700)
Corrected inlet weight flow, kg/sec (lbm/sec):		
Design	396 (873)	403 (889)
Measured	397 (875)	388 (855)
Total pressure ratio:		
Design	1.2	1.2
Measured	1.182	1.171
Thrust, N (lbf):		
Design	70 415 (15 830)	71 705 (16 120)
Measured	59 575 (13 393)	56 412 (12 682)

TABLE III. - FAR-FIELD NOISE OF QF-6 WITH DESIGN NOZZLE

[Data adjusted to standard day of 15° C and 70 percent relative humidity; SPL re 2×10^{-5} N/m^2; PWL re 10^{-13} W.]

(a) Percent of design speed, 60; fan physical speed, 1445 rpm; fundamental blade-passage frequency, 1011 hertz.

FREQUENCY	ANGLE, DEG																AVERAGE SPL	POWER LEVEL (PWL)
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160		
	1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	72.9	69.5	69.0	69.4	70.5	70.5	70.5	67.4	69.7	69.0	70.4	67.8	68.8	70.7	69.9	69.2	69.8	116.8
63	67.2	67.5	66.0	65.2	66.5	67.7	66.3	65.7	65.7	64.5	65.7	66.4	66.3	68.0	68.0	68.2	66.8	113.7
80	70.5	71.0	68.8	66.3	65.8	66.8	66.5	65.8	65.8	65.6	66.1	68.1	67.8	69.1	69.8	70.2	68.0	114.7
100	70.5	68.5	67.3	67.1	65.6	66.6	66.3	66.0	66.0	66.0	67.1	67.9	67.5	69.3	69.6	69.7	69.7	114.6
125	71.8	73.6	72.1	71.5	70.0	70.6	68.6	68.1	68.5	69.6	70.6	69.9	70.8	71.0	69.5	69.2	75.0	117.5
160	73.0	73.8	71.8	70.5	68.5	69.2	68.3	67.8	68.0	68.8	69.7	70.8	69.0	69.7	68.7	68.1	70.5	116.9
200	72.2	72.4	69.9	68.2	67.2	66.4	65.9	66.0	65.9	65.5	66.2	67.5	67.3	68.4	67.5	67.3	68.9	114.7
250	73.0	75.0	72.7	71.2	67.7	67.7	66.0	66.4	67.7	68.4	69.9	72.0	71.8	71.2	69.0	67.3	73.7	117.2
315	74.9	75.1	72.2	70.7	68.9	68.9	67.6	68.4	68.2	69.7	70.7	71.8	71.9	70.9	69.7	67.6	71.7	117.7
400	75.1	76.5	75.0	73.0	70.6	69.6	68.1	68.0	69.1	71.5	73.1	74.7	75.0	73.1	70.5	67.0	73.5	119.6
500	76.5	78.3	77.2	75.5	73.2	71.3	70.0	70.0	70.3	73.0	74.5	75.6	76.0	74.7	71.7	68.0	75.1	121.2
630	76.6	79.5	77.8	76.6	74.6	72.1	70.6	70.8	72.1	74.0	75.6	77.0	77.8	76.5	73.6	69.8	75.9	122.5
800	79.0	80.8	80.2	78.8	76.5	74.5	72.5	73.2	75.0	76.7	77.8	79.6	81.3	79.0	74.7	71.9	78.0	124.9
1000	89.4	91.0	89.5	88.7	87.0	84.2	83.7	82.0	85.5	87.2	88.2	90.5	91.4	87.9	83.0	85.9	87.9	135.1
1250	82.7	84.5	83.0	81.4	79.4	77.0	75.0	74.9	77.4	78.7	80.4	82.3	83.3	81.7	77.5	74.9	80.4	127.6
1600	83.0	84.7	84.0	82.0	80.0	77.2	74.7	75.5	78.4	80.2	82.2	83.1	84.6	83.4	78.2	73.9	81.4	128.6
2000	86.5	88.3	87.2	85.8	84.5	81.3	77.8	77.3	80.8	83.2	85.3	86.1	87.8	87.2	82.8	78.4	84.9	132.1
2500	85.0	85.8	83.8	82.6	80.6	77.6	74.6	74.8	78.0	80.0	83.0	83.9	85.5	85.0	80.6	75.5	82.3	129.6
3150	84.9	85.9	85.1	83.9	82.1	79.2	75.4	74.7	78.6	80.4	82.6	84.5	86.2	86.1	82.2	76.3	83.2	130.4
4000	84.2	85.0	84.3	83.5	81.8	78.7	74.2	74.2	77.7	79.7	82.5	83.0	84.7	84.3	80.3	74.8	82.4	129.7
5000	82.1	82.4	81.2	81.2	78.9	75.9	71.6	71.2	74.9	77.4	80.7	81.5	82.3	81.4	79.7	73.2	80.4	127.4
6300	80.4	81.8	80.9	79.4	77.7	75.6	70.4	69.2	74.1	75.2	78.5	79.3	80.1	80.3	77.3	71.2	79.3	126.5
8000	80.4	81.1	80.1	79.6	76.6	75.1	69.1	67.6	72.9	74.6	77.4	78.1	79.9	79.8	76.4	70.4	79.3	126.4
10000	78.0	78.9	77.9	76.5	73.9	72.2	66.4	64.5	69.5	71.0	74.4	74.7	76.5	75.8	73.2	67.0	77.2	124.2
12500	76.6	77.1	75.6	75.1	72.3	70.1	64.5	61.9	66.6	69.1	72.6	73.8	74.8	74.0	71.1	64.8	76.9	123.9
16000	73.4	74.2	72.4	71.7	68.5	66.3	59.8	57.4	62.9	65.0	68.1	70.2	70.1	70.4	67.1	61.3	75.0	122.0
20000	69.5	69.8	68.5	67.5	64.1	61.2	55.5	53.2	57.4	61.2	63.1	64.5	66.3	66.3	62.6	57.1	73.3	120.3
OVERALL	95.4	96.7	95.5	94.4	92.5	89.9	87.7	86.9	90.0	91.8	93.7	95.1	96.4	95.0	91.1	88.9	93.8	140.9
DISTANCE	SIDELINE PERCEIVED NOISE LEVELS																	
152.5 METERS	67.9	79.7	83.5	85.3	85.7	84.4	82.3	82.4	85.6	87.5	89.1	89.3	89.2	86.4	79.4	71.3		

(b) Percent of design speed, 70; fan physical speed, 1685 rpm; fundamental blade-passage frequency, 1179 hertz.

FREQUENCY	ANGLE, DEG																AVERAGE SPL	POWER LEVEL (PWL)
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160		
	1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	76.0	68.0	66.3	68.5	68.3	68.3	68.5	67.3	68.5	69.6	69.1	71.1	70.1	72.1	73.3	74.5	70.0	117.4
63	75.7	66.7	65.4	67.2	66.7	68.4	67.4	65.7	66.7	66.9	68.1	70.5	69.6	72.2	73.2	73.8	69.2	116.6
80	68.0	68.8	67.3	66.0	65.5	67.0	65.3	65.1	66.1	67.0	67.6	70.4	71.1	73.1	74.3	74.0	69.1	116.5
100	71.0	68.8	68.6	67.6	66.0	67.3	66.3	66.3	68.0	69.1	69.6	72.1	73.0	73.6	74.3	74.4	70.2	117.6
125	73.4	74.1	72.8	71.8	72.1	71.4	69.8	69.3	71.3	72.4	73.4	73.7	73.4	74.3	74.3	73.8	72.5	119.9
160	74.3	74.6	73.8	72.3	71.3	70.9	71.1	70.8	71.4	71.8	72.4	73.7	72.9	73.3	72.9	72.0	72.3	119.7
200	73.8	73.8	71.6	69.1	68.1	67.6	67.9	68.3	68.3	68.1	68.9	70.5	71.1	71.9	72.1	71.0	69.9	117.3
250	75.6	75.8	73.8	71.3	70.3	68.4	67.4	67.9	70.1	71.4	72.3	73.9	73.9	74.1	72.3	70.8	71.9	119.3
315	76.8	75.8	73.5	72.5	71.0	70.0	70.2	70.2	71.8	72.7	73.2	74.1	73.8	73.7	72.5	70.9	72.6	120.0
400	77.7	77.0	77.0	74.5	72.7	71.0	70.9	70.9	72.5	74.2	74.7	76.3	76.2	75.5	72.2	70.4	74.3	121.7
500	78.9	79.4	79.1	77.1	75.6	73.6	72.7	72.6	74.1	76.1	76.7	77.8	77.7	76.2	73.1	71.0	76.1	123.5
630	79.7	81.2	80.1	78.6	76.6	73.7	73.4	73.7	75.9	78.1	79.1	79.8	79.7	78.7	75.2	72.3	77.8	125.2
800	80.6	82.1	82.1	80.1	78.0	75.5	74.6	75.6	77.3	79.3	80.5	81.7	82.3	80.3	75.8	73.0	79.4	126.8
1000	85.4	86.7	85.2	84.4	81.9	80.4	78.7	79.9	81.1	82.7	84.9	87.2	87.1	84.7	79.4	77.6	83.9	131.3
1250	93.5	94.3	92.1	92.0	89.6	88.3	86.1	88.1	88.5	89.0	92.5	96.1	95.8	93.0	87.6	85.7	91.9	139.3
1600	85.2	87.3	87.0	84.8	82.3	80.2	78.2	78.8	81.5	83.3	85.3	86.3	87.2	85.2	79.8	76.1	84.1	131.5
2000	87.8	89.4	88.8	86.4	84.9	82.3	79.4	79.6	83.1	84.9	87.1	88.2	89.4	87.9	82.3	78.5	86.2	133.6
2500	89.4	90.9	90.1	88.8	87.6	85.1	81.8	81.4	84.1	86.1	88.9	90.4	91.8	90.9	85.8	80.5	88.4	135.8
3150	87.1	88.6	88.3	87.1	84.8	82.6	79.4	79.3	82.4	84.4	86.6	88.0	89.3	88.3	82.8	78.3	86.3	133.7
4000	87.0	88.3	88.3	87.7	85.3	83.2	78.8	78.8	82.3	84.3	86.5	87.1	88.8	87.5	82.3	78.1	86.3	133.7
5000	85.4	86.1	85.6	85.9	83.4	81.1	77.2	76.6	80.2	82.6	85.1	86.3	86.7	85.7	81.4	76.5	84.8	132.2
6300	84.1	85.6	85.7	84.2	82.1	80.2	75.6	74.6	79.6	80.9	83.4	83.9	85.1	84.4	80.4	74.8	83.9	131.3
8000	84.2	85.2	84.6	84.1	81.2	79.7	74.7	73.4	78.4	80.1	82.2	83.0	84.6	83.7	79.4	74.4	83.8	131.2
10000	81.9	82.8	82.3	81.4	78.4	77.3	72.4	70.6	75.2	76.8	79.3	79.9	81.4	79.9	76.8	70.9	81.9	129.3
12500	80.3	81.1	80.6	79.4	77.1	75.1	70.2	68.2	72.2	74.9	78.1	78.8	79.6	78.3	75.1	69.1	81.6	129.0
16000	77.1	78.1	76.9	76.0	73.0	71.0	65.2	63.9	68.9	71.1	73.7	75.6	75.4	74.3	71.1	65.0	79.7	127.1
20000	73.0	73.3	72.8	72.7	68.5	66.0	61.0	59.1	63.2	66.8	68.7	69.8	71.3	70.5	67.3	61.1	78.0	125.4
OVERALL	98.6	99.7	98.7	97.8	95.6	93.8	91.0	91.7	93.7	95.2	97.7	99.8	100.3	98.6	93.8	90.6	97.5	144.9
DISTANCE	SIDELINE PERCEIVED NOISE LEVELS																	
152.5 METERS	71.4	82.5	87.0	88.9	89.3	88.6	86.7	87.1	89.9	91.6	93.4	93.9	93.5	90.3	82.4	73.4		

TABLE III. - Continued. FAR-FIELD NOISE OF QF-6 WITH DESIGN NOZZLE

[Data adjusted to standard day of 15° C and 70 percent relative humidity; SPL re 2×10^{-5} N/m^2; PWL re 10^{-13} W.]

(c) Percent of design speed, 80; fan physical speed, 1926 rpm; fundamental blade-passage frequency, 1348 hertz.

FREQUENCY	ANGLE, DEG																AVERAGE SPL	POWER LEVEL (PWL)
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160		
	1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	71.4	68.7	69.7	69.4	70.0	69.2	70.5	71.2	71.4	71.0	72.5	74.3	74.0	75.9	76.9	77.9	72.7	120.1
63	77.7	74.7	69.2	68.4	69.4	69.5	70.4	71.5	71.4	71.5	74.4	73.4	74.7	75.9	76.9	78.4	73.2	120.6
80	69.5	69.6	69.5	68.1	68.1	67.8	67.8	68.3	68.8	70.0	71.5	73.9	75.0	76.6	78.1	79.5	72.6	120.0
100	72.8	71.3	70.7	70.0	69.3	69.5	69.5	69.8	71.2	72.7	74.2	75.9	77.0	78.7	78.7	79.6	74.2	121.6
125	77.0	77.1	76.3	75.1	74.5	73.5	73.5	73.1	74.5	76.0	76.1	77.2	77.1	78.6	78.5	78.4	76.0	123.4
160	77.7	78.1	76.2	75.7	75.6	73.4	73.7	73.7	74.7	75.1	76.2	76.8	76.7	76.7	76.7	76.9	75.7	123.1
200	76.5	76.2	73.5	72.4	71.9	71.2	71.2	71.7	71.7	72.0	72.7	74.1	74.9	76.0	76.7	76.2	73.5	120.9
250	79.0	79.2	76.2	74.0	73.7	72.0	70.7	71.5	73.0	74.0	75.7	76.9	77.5	76.9	76.2	74.9	75.1	122.5
315	79.1	78.6	76.2	76.1	74.9	72.7	72.7	73.9	74.9	76.1	76.7	77.7	77.4	76.4	76.6	75.3	75.9	123.3
400	80.0	79.6	79.3	77.6	75.6	74.3	74.1	74.5	75.1	76.8	78.1	79.2	79.3	77.8	75.8	74.2	77.2	124.6
500	81.1	81.4	80.3	79.3	78.1	75.6	76.3	76.3	76.9	78.4	79.9	80.9	80.4	78.4	76.3	74.5	78.7	126.1
630	81.8	83.2	81.7	80.8	79.5	76.8	76.5	77.3	79.2	80.5	82.3	83.1	82.3	80.5	78.3	75.6	80.5	127.9
800	83.0	84.5	84.2	82.4	80.2	78.0	77.9	79.4	80.9	82.2	83.4	84.4	84.5	81.9	78.5	76.1	82.0	129.4
1000	84.4	85.6	84.3	83.3	81.4	79.6	79.1	80.4	82.1	83.8	84.6	86.5	85.9	82.9	78.9	77.6	83.4	130.8
1250	93.5	94.0	94.2	95.5	93.5	89.7	88.5	87.3	91.8	92.0	94.3	99.8	98.7	93.5	91.3	87.2	94.5	141.9
1600	89.0	90.2	90.2	89.8	87.5	84.8	83.3	83.2	86.7	87.7	89.3	93.1	92.8	89.0	85.2	81.6	89.0	136.4
2000	89.5	90.7	89.5	88.5	86.5	84.8	82.2	83.2	85.8	88.2	89.2	90.4	91.8	88.2	83.5	80.6	88.2	135.6
2500	90.9	92.0	91.9	91.9	90.7	87.7	85.0	85.2	87.0	89.5	91.0	94.1	95.0	92.2	87.2	83.1	91.1	138.5
3150	89.1	90.6	90.4	90.3	88.3	86.6	83.6	83.9	86.6	88.1	89.9	91.4	92.6	89.8	84.8	81.3	89.4	136.8
4000	89.9	91.6	91.1	91.9	89.9	87.7	84.1	84.2	86.7	88.6	90.2	91.0	92.2	89.2	84.7	81.0	90.0	137.4
5000	88.1	88.9	87.9	89.6	87.1	84.9	81.4	81.6	84.3	86.6	88.3	90.1	90.3	87.6	83.6	79.2	88.2	135.6
6300	86.8	88.5	87.8	88.0	86.0	85.0	80.8	79.8	83.5	85.1	86.8	87.7	88.8	86.8	82.1	77.9	87.4	134.8
8000	87.1	88.4	87.6	87.9	85.3	84.8	80.3	79.1	83.4	84.6	86.4	87.2	88.4	86.4	81.8	77.5	87.7	135.1
10000	85.0	85.9	85.2	85.3	82.7	82.4	77.8	76.3	80.2	81.7	83.9	84.3	85.7	83.2	79.4	74.8	86.0	133.4
12500	83.0	84.7	83.0	83.1	81.0	80.5	75.4	73.7	77.6	79.8	82.5	83.2	83.8	81.2	78.0	73.2	85.6	133.0
16000	79.9	81.2	79.5	79.7	77.1	76.3	69.9	69.4	73.9	75.8	78.4	79.9	79.4	78.0	74.3	69.4	83.7	131.1
20000	76.1	76.7	75.7	76.4	72.5	71.4	65.9	64.7	68.8	71.9	73.7	74.4	75.4	74.1	70.4	65.2	82.1	129.5
OVERALL	100.2	101.3	100.8	101.2	99.2	96.8	94.4	94.2	97.3	98.6	100.4	103.4	103.5	100.0	96.6	93.5	100.5	147.9
DISTANCE	SIDELINE PERCEIVED NOISE LEVELS																	
152.5 METERS	72.5	84.1	88.9	92.0	92.6	91.6	90.2	90.9	93.3	95.0	96.0	97.5	96.7	91.9	84.7	76.3		

(d) Percent of design speed, 90; fan physical speed, 2167 rpm; fundamental blade-passage frequency, 1516 hertz.

FREQUENCY	ANGLE, DEG 10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	AVERAGE SPL	POWER LEVEL (PWL)
	1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	73.9	70.9	72.4	72.1	72.8	72.8	73.6	74.4	74.4	74.4	75.4	78.0	76.8	78.6	81.3	81.5	76.0	123.4
63	72.4	72.8	72.1	71.6	71.9	72.3	71.9	72.6	72.6	74.1	74.3	76.9	77.9	78.8	80.9	82.7	75.7	123.1
80	76.8	74.6	71.8	70.8	71.1	71.6	70.6	72.5	73.0	74.0	75.6	77.6	79.5	81.6	82.8	84.4	77.0	124.4
100	75.0	74.3	73.7	73.3	72.5	73.2	72.3	72.8	75.0	76.2	77.5	79.9	81.0	82.3	83.7	84.0	78.1	125.5
125	76.8	80.5	79.6	78.5	77.3	77.3	76.1	76.0	76.8	78.6	79.1	81.2	82.1	82.3	83.3	82.7	79.6	127.0
160	80.6	80.9	79.6	79.3	77.8	77.1	77.1	76.8	78.1	78.1	79.3	80.4	80.1	80.6	81.1	81.3	79.1	126.5
200	79.8	80.0	77.0	75.2	74.7	74.5	74.3	74.8	75.3	75.8	76.7	78.1	79.0	80.0	80.8	80.2	77.2	124.6
250	81.9	83.1	80.1	77.3	76.3	75.6	74.1	74.3	75.8	77.4	79.1	80.2	80.6	80.1	80.6	79.0	78.5	125.9
315	81.7	82.2	79.8	77.8	78.3	76.5	76.7	77.7	78.5	78.5	79.5	80.8	80.3	80.2	80.2	78.7	79.1	126.5
400	82.2	82.7	82.1	79.6	77.7	76.6	76.7	77.1	78.1	79.7	80.6	81.7	81.6	80.6	79.6	77.8	79.8	127.2
500	83.1	83.8	83.0	80.6	79.1	78.3	78.1	79.5	80.1	81.5	82.1	82.9	82.1	80.6	79.3	77.5	81.0	128.4
630	83.6	85.1	83.6	82.6	81.3	79.6	79.6	80.6	82.0	83.1	84.0	84.9	83.6	82.6	80.5	78.0	82.6	130.0
800	85.5	87.0	86.7	84.8	82.7	81.2	81.2	82.5	84.0	85.2	85.8	86.9	85.8	83.5	80.2	78.7	84.5	131.9
1000	85.8	87.5	86.5	85.0	83.3	81.7	82.5	83.3	84.6	86.4	86.9	88.1	86.7	83.3	80.6	79.5	85.3	132.7
1250	87.4	88.9	88.7	87.7	85.9	85.1	84.4	85.1	86.9	89.1	90.2	91.5	89.9	86.1	83.2	81.5	88.1	135.5
1600	95.2	97.0	97.3	97.2	95.5	94.7	93.2	92.2	95.0	96.8	98.5	101.6	99.3	95.0	91.0	90.2	97.0	144.4
2000	91.3	91.7	90.3	89.5	88.2	86.5	85.2	86.0	88.7	90.5	91.7	92.9	93.0	88.2	84.5	82.6	90.0	137.4
2500	90.9	91.6	90.8	90.5	89.1	87.3	86.0	86.8	89.1	91.3	92.3	93.9	93.6	89.5	84.8	82.8	90.8	138.2
3150	92.6	95.4	95.7	95.1	94.2	92.1	89.7	89.4	91.7	93.2	94.1	96.3	96.7	93.2	88.6	85.5	94.2	141.6
4000	91.0	92.3	92.6	92.3	90.5	89.1	86.5	87.3	90.1	92.1	92.8	93.7	93.8	90.0	86.0	82.7	91.9	139.3
5000	90.1	91.3	90.8	91.8	89.6	88.3	85.6	85.6	88.4	90.8	91.6	93.9	93.3	90.3	85.8	82.4	91.4	138.8
6300	88.7	90.5	90.5	89.5	87.9	87.0	84.0	83.7	87.5	89.2	90.2	91.1	92.0	90.2	84.4	81.1	90.4	137.8
8000	88.7	90.1	89.5	89.8	87.8	87.3	83.5	83.0	87.1	88.8	90.2	90.8	92.0	89.8	84.3	80.6	90.8	138.2
10000	86.3	87.4	87.1	86.9	84.9	84.8	80.9	80.1	84.4	85.6	87.6	87.8	88.8	85.9	82.4	77.7	88.9	136.3
12500	84.4	85.9	84.7	84.4	83.2	82.6	78.4	77.9	81.5	84.0	86.5	87.1	87.0	84.4	80.7	76.1	88.6	136.0
16000	80.6	82.6	81.2	81.3	79.0	78.3	73.3	73.8	78.1	80.1	82.2	83.8	82.9	80.9	77.3	72.5	86.7	134.1
20000	76.7	77.7	77.3	77.5	74.0	72.9	69.0	69.0	72.7	76.3	78.2	78.5	79.4	77.2	73.5	68.7	85.1	132.5
OVERALL	101.7	103.3	103.0	102.7	101.1	99.9	98.0	97.9	100.5	102.3	103.5	105.5	104.8	101.5	98.0	96.4	102.9	150.3
DISTANCE	SIDELINE PERCEIVED NOISE LEVELS																	
152.5 METERS	75.2	86.7	91.6	94.3	95.3	95.2	94.3	94.9	97.3	98.8	99.5	100.8	98.6	93.2	86.4	80.2		

TABLE III. - Concluded. FAR-FIELD NOISE OF QF-6 WITH DESIGN NOZZLE

[Data adjusted to standard day of 15° C and 70 percent relative humidity; SPL re 2×10^{-5} N/m^2; PWL re 10^{-13} W.]

(e) Percent of design speed, 100; fan physical speed, 2408 rpm; fundamental blade-passage frequency, 1685 hertz.

FREQUENCY	ANGLE, DEG																AVERAGE SPL	POWER LEVEL (PWL)
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160		
	1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	76.6	75.0	75.1	76.0	75.3	75.8	76.6	77.0	76.6	78.1	78.1	80.5	81.3	82.8	85.1	86.7	79.6	127.0
63	72.3	75.1	73.9	73.6	74.8	74.6	74.9	75.1	75.3	76.3	77.1	79.7	81.3	83.8	84.9	85.7	79.0	126.4
80	79.3	77.6	75.1	74.9	74.8	74.1	74.6	73.3	75.3	76.8	78.8	81.7	82.9	84.9	87.3	87.8	80.5	127.9
100	77.3	76.3	75.3	75.6	74.8	75.3	75.1	75.6	77.6	79.5	81.1	84.4	84.5	86.6	87.5	88.2	81.8	129.2
125	82.1	83.1	81.9	80.6	79.6	79.8	78.9	79.3	80.3	81.6	83.1	84.9	85.1	85.8	87.4	86.7	82.9	130.3
160	81.8	82.8	82.6	82.0	80.0	80.5	79.5	80.5	80.8	81.6	82.6	84.4	83.3	84.1	85.0	84.7	82.3	129.7
200	82.2	83.2	79.7	78.8	77.7	77.6	78.0	77.5	78.3	78.6	80.2	81.7	82.8	84.0	84.8	84.4	80.7	128.1
250	84.6	85.6	83.3	81.1	79.0	77.8	76.6	77.5	79.1	80.3	82.1	83.7	83.8	84.0	84.1	83.0	81.7	129.1
315	83.2	83.8	82.0	81.3	79.7	78.2	78.8	80.0	80.8	81.8	82.5	84.2	84.0	84.2	83.8	82.2	82.0	129.4
400	84.5	85.0	85.0	83.2	80.5	79.5	79.9	80.2	81.2	82.9	83.0	84.1	84.4	83.7	82.9	81.1	82.7	130.1
500	84.4	85.4	84.4	83.5	82.2	80.9	80.7	81.9	83.2	84.2	84.2	84.8	84.2	83.7	82.5	80.6	83.4	130.8
630	84.5	85.9	84.9	84.6	82.9	81.4	81.9	82.9	84.5	86.2	86.2	86.5	85.0	84.5	83.2	80.8	84.6	132.0
800	86.5	88.3	87.8	87.3	85.3	83.6	83.6	85.0	86.3	87.6	87.8	88.9	87.1	85.5	82.5	81.2	86.5	133.9
1000	86.8	88.3	87.5	87.2	85.2	84.5	85.2	86.3	87.3	88.5	89.0	89.4	88.0	85.3	83.0	81.6	87.2	134.6
1250	87.3	89.0	88.6	87.8	86.3	85.3	86.0	86.3	88.9	90.1	90.3	91.2	90.6	86.1	83.8	82.3	88.6	136.0
1600	96.8	100.3	101.2	102.5	100.5	98.7	98.2	97.2	98.0	98.8	100.2	105.1	105.8	97.3	93.7	92.6	101.0	148.4
2000	92.6	93.9	93.7	94.6	92.6	91.2	90.2	90.3	91.8	93.8	94.6	97.2	98.1	92.3	88.9	86.6	94.0	141.4
2500	90.1	91.3	90.8	90.4	88.8	87.8	87.8	88.8	90.9	92.8	93.8	95.2	95.1	89.4	86.1	83.8	91.9	139.3
3150	93.0	96.8	97.2	96.7	96.0	94.2	93.2	92.2	94.2	95.7	97.2	98.8	97.8	93.2	89.8	87.6	96.2	143.6
4000	91.2	93.0	92.8	92.5	91.5	90.3	89.7	90.2	93.0	94.5	95.3	96.3	96.2	91.2	88.3	85.2	93.9	141.3
5000	90.4	92.1	91.3	92.9	90.8	90.1	88.6	88.8	91.4	93.4	94.9	96.7	96.1	91.8	88.1	84.7	93.8	141.2
6300	87.9	90.6	90.2	90.3	88.2	88.6	86.3	86.7	90.9	92.2	93.2	94.2	94.6	91.4	86.7	83.3	92.6	140.0
8000	87.7	89.7	89.1	89.4	87.4	88.1	85.1	86.2	90.7	92.1	93.2	94.0	94.9	91.1	87.1	83.5	93.0	140.4
10000	85.2	86.7	86.2	86.2	84.4	85.4	82.6	83.4	87.7	89.2	90.9	90.9	92.1	88.1	85.1	80.6	91.2	138.6
12500	82.7	84.5	83.5	83.9	82.9	83.1	80.1	81.0	85.2	87.9	90.0	90.2	90.5	86.4	83.7	79.2	91.1	138.5
16000	79.0	81.0	80.1	80.0	78.1	78.5	74.8	77.1	81.7	83.7	86.1	87.3	86.1	83.7	79.7	75.6	89.2	136.6
20000	74.1	75.5	75.4	75.6	72.9	73.0	71.3	72.8	76.7	80.5	81.8	82.0	82.5	80.0	76.7	71.6	87.6	135.0
OVERALL	103.0	104.8	105.0	105.6	103.8	102.5	101.7	101.5	103.3	104.7	105.9	108.5	108.8	103.3	100.8	99.4	105.7	153.1
DISTANCE	SIDELINE PERCEIVED NOISE LEVELS																	
152.5 METERS	77.6	89.0	94.0	97.6	97.8	97.8	98.1	98.3	100.0	101.3	101.9	103.9	102.8	94.9	89.1	82.9		

TABLE IV. - FAR-FIELD NOISE OF QF-9 WITH DESIGN NOZZLE

[Data adjusted to standard day of 15° C and 70 percent relative humidity; SPL re 2×10^{-5} N/m^2; PWL re 10^{-13} W.]

(a) Percent of design speed, 60; fan physical speed, 1331 rpm; fundamental blade-passage frequency, 332 hertz.

FREQUENCY	ANGLE, DEG																AVERAGE SPL	POWER LEVEL (PWL)
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160		
	1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	69.2	65.2	66.0	67.8	68.2	68.2	69.0	68.2	66.3	66.8	67.2	66.3	67.5	67.0	67.2	68.4	67.5	114.9
63	63.0	64.0	64.3	65.0	65.0	63.5	63.3	63.7	63.0	63.8	65.2	65.3	65.8	66.5	66.8	67.9	64.8	112.2
80	65.2	66.3	66.7	67.0	66.0	69.0	67.5	64.7	65.8	66.0	65.5	65.9	67.2	69.0	68.3	68.6	66.9	114.3
100	69.3	69.8	70.5	70.2	67.5	68.5	68.0	67.5	68.5	70.7	69.5	67.1	69.3	72.0	68.8	68.7	69.2	116.6
125	73.7	75.8	75.2	73.2	73.5	71.3	70.8	71.3	71.0	73.3	74.2	71.3	72.8	73.0	71.7	70.2	72.7	120.1
160	72.5	74.7	74.2	72.2	71.5	70.4	69.5	70.2	70.2	70.5	72.2	71.4	71.9	72.4	69.9	69.1	71.4	118.8
200	75.5	76.4	74.2	71.5	69.7	68.5	68.2	70.2	68.7	68.2	69.2	67.8	70.5	70.5	69.4	69.3	70.4	117.8
250	82.2	81.9	79.2	76.9	75.0	73.9	71.7	71.7	72.4	73.9	75.2	75.0	77.7	78.0	75.9	71.7	75.9	123.3
315	92.4	90.4	90.7	91.1	90.1	87.1	85.2	83.6	86.6	86.4	89.1	88.8	88.1	87.9	87.6	85.0	88.2	135.6
400	84.3	84.6	84.5	82.8	81.5	79.3	77.0	77.0	78.5	79.6	81.1	80.7	81.8	81.1	78.6	75.7	80.8	128.2
500	82.2	82.9	82.2	80.7	79.2	76.5	74.9	74.9	75.5	77.2	78.9	77.5	80.0	81.4	78.4	74.8	78.8	126.2
630	84.8	85.7	85.7	85.7	83.0	80.3	79.7	80.0	81.8	82.0	83.2	82.2	85.8	86.0	83.0	79.0	83.3	130.7
800	82.3	83.5	83.7	82.5	80.3	77.5	75.7	76.2	77.0	78.7	80.8	80.4	83.3	84.0	79.7	75.2	80.6	128.0
1000	84.0	84.5	83.4	83.0	80.7	78.2	76.0	76.7	77.5	79.7	82.0	82.0	85.5	85.7	80.7	76.4	81.7	129.1
1250	82.2	82.7	82.2	81.3	80.2	77.0	74.3	74.5	75.3	77.8	79.8	79.4	83.0	83.7	78.8	74.4	79.9	127.3
1600	86.5	81.8	81.3	80.5	79.0	76.2	72.7	72.2	73.7	75.8	78.3	77.6	82.5	82.8	78.0	71.9	78.8	126.2
2000	79.4	80.6	80.4	79.9	77.6	74.6	70.4	70.2	72.1	73.9	76.9	76.2	80.9	80.7	76.1	70.3	77.4	124.8
2500	78.0	79.0	78.2	77.7	75.8	72.8	69.5	68.0	70.3	72.7	75.2	74.4	79.0	78.2	74.8	68.6	75.6	123.0
3150	77.5	78.5	77.8	77.0	74.8	72.3	68.6	67.0	69.5	72.0	74.6	73.6	77.3	77.8	73.8	67.9	75.0	122.4
4000	77.1	77.8	77.5	77.5	75.1	71.1	67.1	66.0	68.1	70.3	73.0	72.3	77.3	77.1	73.3	67.6	74.7	122.1
5000	76.0	75.9	75.9	77.0	73.5	69.5	65.0	63.7	66.2	68.9	71.9	70.0	75.7	74.5	73.4	65.1	73.5	120.9
6300	75.2	76.9	75.0	75.7	72.5	70.5	66.0	62.5	67.2	69.7	72.7	71.7	74.9	75.9	72.9	65.5	74.0	121.4
8000	76.1	76.1	75.5	76.1	73.0	68.8	64.6	62.1	66.1	68.8	71.6	70.3	75.7	75.0	71.1	65.1	74.3	121.7
10000	73.4	73.7	72.9	74.0	70.2	66.9	62.2	59.7	64.4	65.9	69.5	68.1	73.5	72.7	69.7	62.4	73.0	120.4
12500	71.2	71.7	70.5	72.5	68.8	64.7	59.6	56.9	61.9	64.2	67.7	66.4	72.0	70.3	67.3	59.9	72.5	119.9
16000	67.9	68.9	67.7	68.3	65.0	61.1	55.7	53.0	57.4	60.7	63.9	63.5	68.0	67.4	65.1	57.6	70.9	118.3
20000	64.8	64.9	63.8	64.3	60.2	56.0	51.2	49.8	53.1	57.1	59.6	59.1	64.3	63.4	61.4	53.2	69.6	117.0
OVERALL	95.8	95.5	95.3	95.0	93.4	90.6	88.7	88.1	90.0	90.8	92.9	92.4	94.5	94.6	91.9	88.4	92.8	140.2
DISTANCE	SIDELINE PERCEIVED NOISE LEVELS																	
152.8 METERS	70.0	77.7	81.8	84.3	84.5	83.0	81.4	81.0	83.3	84.2	86.1	84.6	85.5	83.7	78.3	70.4		

TABLE IV. - Continued. FAR-FIELD NOISE OF QF-9 WITH DESIGN NOZZLE

[Data adjusted to standard day of 15° C and 70 percent relative humidity; SPL re 2×10^{-5} N/m^2; PWL re 10^{-13} W.]

(b) Percent of design speed, 70; fan physical speed, 1553 rpm; fundamental blade-passage frequency, 388 hertz.

FREQUENCY	ANGLE, DEG																AVERAGE SPL	POWER LEVEL (PWL)
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160		
	1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	76.2	69.4	67.6	70.2	71.7	70.6	71.6	67.7	68.7	69.2	68.2	68.2	71.1	71.1	70.6	75.3	70.4	117.8
63	64.9	67.8	67.3	65.8	69.9	66.9	66.6	65.6	65.6	67.6	66.4	67.0	70.1	72.3	71.3	75.8	68.7	116.1
80	67.1	68.6	67.9	66.7	69.6	66.9	65.7	65.9	66.2	67.2	68.4	67.3	70.7	72.2	72.4	76.3	69.1	116.5
100	73.9	74.4	73.4	72.8	71.4	73.4	70.6	68.8	71.1	71.9	72.1	71.5	74.3	74.4	74.8	76.6	72.7	120.1
125	75.5	76.7	75.7	76.0	76.0	73.2	74.0	73.4	74.5	75.2	75.9	74.3	75.4	76.0	76.0	77.3	75.2	122.6
160	76.3	76.8	76.6	75.0	74.6	73.1	72.6	73.0	74.0	74.5	75.3	75.0	76.0	75.6	73.5	75.7	74.7	122.1
200	77.5	77.2	75.7	73.2	72.7	70.9	70.0	69.9	70.2	70.9	71.9	71.6	74.0	73.5	73.4	75.1	72.7	120.1
250	81.4	81.1	79.2	78.4	77.1	75.4	73.2	73.2	74.6	76.2	77.7	77.6	79.9	79.1	76.7	76.6	77.3	124.7
315	88.3	87.5	85.5	83.0	83.5	82.0	79.3	77.6	78.1	79.6	81.6	81.7	82.3	82.5	78.6	79.0	82.0	129.4
400	98.3	96.7	98.8	94.7	97.8	96.5	93.2	88.0	87.2	90.5	94.0	95.4	94.0	95.2	89.3	89.4	94.5	141.9
500	85.3	85.0	85.3	84.0	82.8	81.0	79.1	78.5	80.0	82.1	82.8	82.2	83.8	83.8	80.3	80.0	82.4	129.8
630	85.2	85.2	85.5	83.7	82.0	79.4	77.5	77.7	79.9	81.7	82.7	82.5	85.7	85.9	80.2	79.6	82.6	130.0
800	89.3	89.6	90.1	88.9	87.4	85.6	84.4	85.1	87.1	87.3	88.8	89.4	90.8	92.1	86.9	86.0	88.4	135.8
1000	85.5	86.1	85.8	84.5	83.1	81.0	79.0	79.0	80.6	82.8	84.8	84.4	86.8	85.6	80.5	80.7	83.6	131.0
1250	86.2	87.2	87.4	85.9	84.9	81.5	79.7	79.9	81.0	83.0	84.9	86.5	88.4	87.4	82.2	81.8	84.9	132.3
1600	84.9	85.4	85.9	85.2	84.0	81.0	77.4	77.2	79.4	81.5	83.4	83.3	87.7	86.9	81.0	79.1	83.6	131.0
2000	83.6	84.1	84.7	83.9	82.7	79.9	75.9	75.1	77.1	79.7	81.6	81.2	85.7	84.7	79.4	77.3	82.0	129.4
2500	81.8	82.4	82.1	82.3	81.1	78.4	74.4	73.1	75.3	78.1	80.4	79.9	83.4	82.8	77.8	76.2	80.3	127.7
3150	81.1	81.1	81.6	81.1	79.8	77.6	74.1	71.8	74.5	77.1	79.5	78.6	81.8	81.6	76.3	75.2	79.4	126.8
4000	80.9	81.2	81.5	81.9	80.0	76.7	72.2	71.0	73.4	75.7	77.7	77.6	81.4	80.2	75.4	74.4	79.0	126.4
5000	79.2	79.0	79.4	80.7	78.2	74.7	70.2	68.2	71.0	73.7	76.7	75.3	80.2	77.7	75.4	71.8	77.6	125.0
6300	78.7	79.7	78.6	79.2	77.0	76.1	71.1	67.5	72.6	74.7	77.1	76.4	78.9	79.1	75.0	72.5	78.0	125.4
8000	79.1	79.3	78.8	79.3	77.0	74.3	69.3	67.1	71.5	73.6	75.8	74.8	79.5	78.1	73.8	71.8	78.1	125.5
10000	76.6	76.3	76.1	77.5	74.3	72.4	66.6	64.8	69.4	71.1	74.1	72.8	77.5	75.9	72.6	69.5	76.9	124.3
12500	74.8	74.3	73.4	75.2	72.6	70.0	64.2	62.5	66.9	69.3	71.9	71.5	76.1	73.6	70.6	67.0	76.3	123.7
16000	71.2	71.7	70.5	71.2	68.8	65.9	60.4	58.1	63.1	65.7	68.2	67.5	71.9	70.7	68.6	64.6	74.6	122.0
20000	67.8	66.9	66.4	67.2	64.2	60.8	56.1	54.6	58.6	61.9	63.7	63.6	68.3	66.4	64.8	60.2	73.2	120.6
OVERALL	99.5	99.8	100.9	98.3	99.5	97.9	94.9	92.0	92.9	94.9	97.3	98.1	98.9	99.3	94.1	93.9	97.6	145.0
DISTANCE	SIDELINE PERCEIVED NOISE LEVELS																	
152.5 METERS	74.3	82.7	87.9	88.3	90.9	90.4	88.1	85.6	86.7	89.0	91.0	90.7	90.5	88.9	81.1	76.5		

(c) Percent of design speed, 86; fan physical speed, 1902 rpm; fundamental blade-passage frequency, 475 hertz.

FREQUENCY	ANGLE, DEG																AVERAGE SPL	POWER LEVEL (PWL)
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160		
	1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	71.8	67.8	70.1	70.3	71.8	72.1	72.9	73.4	73.3	74.6	75.4	73.0	75.1	76.1	77.4	78.1	74.0	121.4
63	79.3	73.1	70.6	69.9	71.1	73.4	76.4	72.3	73.9	74.1	75.1	71.4	75.9	76.6	77.8	79.5	74.7	122.1
80	70.9	70.5	69.5	68.7	70.0	70.7	71.0	71.2	70.9	73.0	74.7	73.1	76.2	77.7	79.2	80.1	74.0	121.4
100	76.6	76.6	75.7	75.1	73.6	74.9	75.1	75.2	75.9	78.1	78.7	77.0	79.1	79.1	80.4	80.1	77.2	124.6
125	81.5	82.6	82.6	80.0	78.0	77.1	77.0	79.1	79.0	80.6	82.1	79.9	81.8	80.8	81.0	79.7	80.2	127.6
160	79.5	79.8	79.8	79.0	77.1	77.3	76.5	78.0	78.1	79.3	79.8	79.9	80.1	79.3	79.1	78.0	78.8	126.2
200	81.1	82.1	80.8	79.3	77.3	76.4	74.6	75.6	75.6	76.1	77.9	76.5	78.6	78.1	78.8	77.8	77.7	125.1
250	85.0	86.7	83.7	82.3	81.3	79.5	78.0	79.8	80.5	81.8	83.5	81.9	83.8	83.2	80.8	78.9	82.0	129.4
315	88.6	87.9	86.3	84.6	81.9	79.8	79.8	80.3	81.1	82.3	84.1	82.5	84.3	84.1	81.3	80.3	83.1	130.5
400	99.0	92.9	93.2	92.0	90.5	86.4	85.7	84.9	86.2	88.5	89.9	88.3	91.4	90.2	85.7	83.8	89.5	136.9
500	105.7	101.2	103.7	101.4	100.6	95.7	93.9	91.4	95.2	97.6	97.7	94.8	100.7	99.7	94.7	92.8	98.7	146.1
630	90.1	89.7	89.7	88.6	86.7	83.2	82.4	83.2	85.2	87.7	88.9	87.5	90.1	88.7	83.4	81.5	87.3	134.7
800	89.6	89.9	90.4	89.1	87.4	85.4	84.6	85.3	86.6	88.8	90.1	88.9	91.8	91.3	84.9	82.5	88.6	136.0
1000	91.3	93.3	93.3	93.3	92.1	91.1	87.3	88.3	90.3	91.5	93.1	92.9	96.0	94.1	88.3	86.7	92.2	139.6
1250	88.7	89.9	90.4	89.2	87.2	84.7	83.4	84.2	85.9	87.7	89.9	88.8	91.5	88.7	84.0	81.4	88.1	135.5
1600	88.8	90.5	91.3	90.6	88.6	86.5	83.8	84.3	85.8	87.6	89.6	88.7	93.5	90.1	84.3	81.3	88.9	136.3
2000	88.4	89.9	90.4	89.9	88.0	85.4	82.5	82.7	84.5	86.2	88.4	88.1	91.7	89.2	83.4	80.4	87.9	135.3
2500	86.9	87.7	88.5	88.4	86.5	84.5	81.7	81.0	82.7	85.0	87.0	86.0	89.5	87.0	81.9	78.6	86.3	133.7
3150	86.1	87.1	87.6	87.9	85.9	84.6	81.7	80.1	81.7	84.4	86.2	85.5	87.6	86.6	80.7	77.8	85.7	133.1
4000	85.9	86.9	87.2	87.5	85.2	82.9	79.7	78.7	80.7	82.5	84.2	83.8	87.0	84.7	79.5	76.4	84.8	132.2
5000	84.4	84.7	85.6	86.7	83.1	80.6	77.4	76.2	78.1	80.1	82.7	81.4	85.4	82.4	79.4	73.8	83.3	130.7
6300	83.6	84.9	83.6	84.9	81.9	81.6	77.9	74.9	79.3	80.7	83.2	82.1	84.2	83.1	78.1	74.5	83.4	130.8
8000	83.7	84.1	83.8	84.7	81.5	79.5	75.8	74.7	78.3	79.3	81.6	80.8	84.7	82.5	77.2	73.3	83.3	130.7
10000	80.6	81.1	80.6	82.3	78.4	76.7	72.6	72.2	76.1	76.9	80.3	78.9	82.4	79.9	76.1	70.8	81.9	129.3
12500	78.3	78.8	77.9	80.2	76.6	74.7	70.2	69.7	73.7	75.1	78.3	77.2	81.0	77.8	74.5	68.7	81.3	128.7
16000	74.3	75.9	74.6	75.5	72.3	70.0	65.8	65.7	69.7	71.6	74.7	73.7	77.4	75.5	72.6	66.6	79.6	127.0
20000	71.3	71.1	70.4	71.2	67.6	64.8	60.8	61.4	65.4	67.6	69.7	69.8	73.6	71.4	69.1	62.2	78.1	125.5
OVERALL	107.0	104.3	105.7	104.2	102.9	99.4	97.4	96.6	99.0	101.0	102.1	100.6	104.6	103.1	98.3	96.4	102.1	149.5
DISTANCE	SIDELINE PERCEIVED NOISE LEVELS																	
152.5 METERS	81.4	87.2	92.8	94.2	94.6	92.6	91.4	90.8	93.5	95.4	96.1	93.5	96.4	93.0	85.6	79.2		

TABLE IV. - Continued. FAR-FIELD NOISE OF QF-9 WITH DESIGN NOZZLE

[Data adjusted to standard day of 15° C and 70 percent relative humidity; SPL re 2×10^{-5} N/m^2; PWL re 10^{-13} W.]

(d) Percent of design speed, 93; fan physical speed, 2063 rpm; fundamental blade-passage frequency, 515 hertz.

FREQUENCY	ANGLE, DEG																AVERAGE SPL	POWER LEVEL (PWL)
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160		
	1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	73.8	71.3	72.7	72.6	73.3	72.6	72.3	73.7	73.5	75.1	74.7	74.5	77.3	78.1	79.2	81.6	75.3	122.7
63	72.5	74.5	73.1	72.2	72.2	74.3	73.6	72.0	73.2	74.7	73.5	74.7	77.6	78.8	80.0	81.9	75.5	122.9
80	73.5	74.3	72.2	70.5	71.4	72.3	71.9	71.8	72.0	74.5	75.5	75.7	78.9	79.9	81.4	82.7	76.0	123.4
100	80.6	79.4	78.0	79.6	79.4	78.2	76.0	77.2	78.1	79.7	81.1	80.0	81.9	83.1	83.6	83.1	80.1	127.5
125	80.5	83.0	83.2	81.5	79.7	79.9	79.4	80.4	81.4	82.0	83.0	82.0	84.2	83.4	83.1	82.4	81.9	129.3
160	82.3	82.6	82.0	81.2	79.7	80.0	78.8	80.2	81.2	81.8	82.8	82.7	83.3	81.8	81.3	81.1	81.5	128.9
200	83.5	84.0	81.7	79.0	78.3	77.6	76.2	76.8	77.3	78.5	79.5	79.1	81.5	81.5	80.6	80.2	79.5	126.9
250	86.1	86.5	85.3	83.9	83.0	82.3	80.3	80.3	81.9	83.3	83.9	83.9	86.3	85.1	82.4	81.0	83.5	130.9
315	88.1	88.0	87.2	85.0	83.7	83.0	82.0	83.4	84.0	85.9	86.4	86.2	87.4	84.9	82.1	80.9	85.1	132.5
400	90.6	91.6	91.7	88.2	86.6	85.5	84.2	85.0	86.1	87.6	88.3	88.1	90.2	88.1	83.7	83.0	87.8	135.2
500	101.1	102.9	100.6	98.4	99.1	96.9	96.9	97.2	97.2	97.8	97.3	98.6	101.8	102.3	95.4	94.6	99.0	146.4
630	92.1	93.6	91.8	90.7	89.0	87.3	86.3	87.3	89.0	91.0	91.0	90.9	94.0	91.8	86.3	84.9	90.4	137.8
800	90.0	91.0	91.3	89.5	88.5	87.0	87.0	87.9	90.2	91.7	92.0	91.7	94.7	91.7	85.5	83.8	90.6	138.0
1000	94.5	95.0	97.0	94.0	94.5	91.5	90.6	91.3	92.3	93.5	95.6	97.5	97.2	93.5	88.6	86.7	94.3	141.7
1250	89.8	91.1	91.8	90.8	89.2	87.2	85.8	87.1	89.0	90.2	91.5	91.6	93.3	89.8	85.2	83.3	90.1	137.5
1600	91.3	92.3	93.3	93.2	91.7	90.3	87.3	88.7	89.5	90.7	92.0	92.5	97.0	91.7	86.5	83.5	91.9	139.3
2000	90.1	91.4	91.6	91.6	90.5	88.7	85.7	85.7	87.4	88.9	90.1	90.5	94.4	90.2	85.0	82.0	90.1	137.5
2500	88.4	89.4	90.1	90.5	89.1	87.5	84.9	84.0	85.9	87.4	89.2	89.0	92.2	88.7	83.5	80.6	88.7	136.1
3150	88.0	88.8	89.3	89.6	88.2	86.8	84.6	83.2	85.3	87.1	88.6	88.0	90.5	87.6	82.3	79.6	88.0	135.4
4000	87.6	88.4	88.7	89.6	87.7	85.5	82.7	82.2	84.1	85.6	87.0	86.8	90.4	87.0	81.6	78.5	87.4	134.8
5000	85.9	86.1	86.6	87.9	85.2	82.9	80.2	79.6	81.3	82.9	85.2	84.0	88.6	84.2	81.3	75.9	85.5	132.9
6300	84.8	86.3	85.3	86.4	83.4	83.7	80.1	78.2	82.2	83.6	85.3	84.8	87.1	85.1	80.4	76.5	85.6	133.0
8000	84.7	85.8	85.2	85.9	83.1	81.4	77.8	77.6	81.2	82.2	84.2	83.1	87.5	84.1	79.2	75.5	85.4	132.8
10000	82.2	82.6	82.0	83.5	80.2	79.0	74.9	75.2	79.3	80.0	82.4	81.0	85.4	81.7	78.1	73.2	84.1	131.5
12500	79.7	80.1	79.6	81.5	78.1	77.0	72.6	73.0	77.0	78.3	80.5	79.4	84.1	79.9	76.3	70.8	83.6	131.0
16000	75.3	76.7	75.9	76.5	73.6	72.2	68.0	68.5	72.9	74.9	76.9	76.0	80.1	77.3	74.5	68.3	81.7	129.1
20000	71.8	71.7	71.4	72.0	68.6	66.4	63.1	64.6	68.4	70.7	72.2	72.2	75.9	73.5	71.2	64.3	80.1	127.5
OVERALL	104.4	105.8	105.0	103.6	103.1	101.1	100.1	100.5	101.4	102.5	103.3	103.9	106.5	104.9	99.4	98.1	103.4	150.8
DISTANCE	SIDELINE PERCEIVED NOISE LEVELS																	
152.5 METERS	79.1	88.8	92.1	93.6	95.0	94.5	94.1	94.9	96.0	97.0	97.2	96.7	98.4	95.0	86.8	81.0		

(e) Percent of design speed, 100; fan physical speed, 2164 rpm; fundamental blade-passage frequency, 541 hertz.

FREQUENCY	ANGLE, DEG																AVERAGE SPL	POWER LEVEL (PWL)
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160		
	1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	75.4	73.2	75.0	74.7	75.0	75.9	76.5	76.2	77.0	77.0	77.5	78.6	79.4	80.9	82.5	85.6	78.3	125.7
63	73.3	74.8	73.5	73.8	74.7	74.8	76.2	75.8	76.3	77.0	77.3	78.6	80.5	82.2	83.7	85.9	78.6	126.0
80	76.6	79.0	75.3	74.8	76.0	78.5	78.1	78.5	79.1	80.3	81.0	81.5	83.5	84.3	85.3	86.5	80.9	128.3
100	81.5	81.0	81.0	81.6	78.1	80.6	80.1	79.5	81.3	83.8	83.5	84.4	85.1	86.1	86.1	86.4	83.0	130.4
125	84.0	85.9	85.4	82.4	83.2	82.9	82.4	82.9	83.9	85.9	86.4	86.6	86.9	86.5	86.0	85.6	85.0	132.4
160	85.9	85.4	86.6	82.7	85.1	83.4	83.9	83.9	85.4	87.1	86.4	88.6	85.9	86.2	85.6	84.9	85.7	133.1
200	86.1	87.6	85.6	82.2	81.2	81.4	80.9	80.9	81.4	82.2	83.9	84.1	85.1	84.6	84.2	83.6	83.3	130.7
250	88.1	88.7	86.6	85.4	84.1	83.9	82.6	83.6	84.4	86.2	87.2	88.7	88.7	87.4	84.6	83.6	86.1	133.5
315	89.6	90.6	91.2	87.4	87.2	88.2	86.2	87.9	88.1	91.1	91.7	90.5	91.2	89.9	86.2	85.1	89.4	136.8
400	90.1	92.6	91.4	89.4	89.1	86.7	86.8	87.6	88.6	90.7	91.6	92.7	92.9	89.1	85.7	85.1	90.1	137.5
500	98.5	100.1	99.0	100.8	96.3	96.3	98.8	97.5	96.6	97.1	98.8	101.7	101.5	97.1	91.1	94.9	98.7	146.1
630	93.3	94.7	94.0	94.5	91.3	90.8	92.3	91.8	93.0	95.0	95.5	96.6	97.2	93.7	89.3	88.9	94.1	141.5
800	90.1	91.4	91.9	91.1	89.4	89.4	89.4	91.4	93.4	94.9	95.4	95.3	97.2	94.1	89.1	87.3	93.3	140.7
1000	92.8	95.5	95.8	97.3	94.0	92.7	92.2	93.2	94.8	96.5	97.0	99.3	99.0	95.7	90.5	88.9	95.9	143.3
1250	90.2	92.9	92.9	92.7	90.7	89.7	89.6	90.7	92.7	94.2	95.4	96.7	96.2	92.6	88.6	87.1	93.4	140.8
1600	91.7	93.4	93.9	93.2	92.9	91.2	89.6	90.9	92.4	94.7	95.2	96.2	98.2	92.7	87.7	86.1	93.9	141.3
2000	89.8	92.1	91.8	91.6	90.5	89.1	87.3	88.1	90.5	92.3	93.8	94.1	96.6	90.8	86.3	84.2	92.1	139.5
2500	88.3	90.7	90.3	90.3	89.2	87.7	86.5	86.5	88.5	91.0	92.2	93.0	94.2	89.7	84.7	82.8	90.6	138.0
3150	87.9	90.2	89.7	89.7	88.2	87.0	86.0	86.0	87.7	90.7	92.0	92.5	93.0	89.4	83.9	81.6	90.2	137.6
4000	88.0	90.0	89.5	89.8	87.7	86.1	84.1	85.3	87.3	89.0	90.3	91.3	92.5	88.3	83.8	81.1	89.5	136.9
5000	86.3	88.0	87.0	88.5	85.6	83.7	82.0	82.6	85.0	86.8	89.0	89.0	91.1	86.2	82.0	79.5	87.9	135.3
6300	85.7	87.7	86.0	86.2	83.1	84.3	81.5	81.0	83.7	87.0	88.8	89.5	89.5	87.0	81.2	77.7	87.8	135.2
8000	86.2	87.8	86.1	86.6	82.9	82.6	80.2	80.2	84.1	85.7	87.9	87.9	90.0	86.2	82.0	78.0	87.9	135.3
10000	84.2	85.9	83.5	84.5	80.7	81.0	77.9	78.5	81.9	83.5	85.9	85.8	87.9	84.5	80.0	75.7	86.8	134.2
12500	82.7	84.3	82.2	83.7	79.2	79.7	76.7	77.5	81.0	82.7	84.8	85.0	87.0	83.2	80.0	76.0	87.2	134.6
16000	79.4	81.6	79.6	79.7	75.7	75.9	73.2	74.2	77.4	79.9	81.7	82.1	83.4	80.9	76.2	73.0	85.9	133.3
20000	75.9	78.3	75.8	76.4	71.8	72.1	69.6	71.6	75.0	77.1	78.1	79.0	80.9	78.1	74.0	69.4	85.6	133.0
OVERALL	103.7	105.4	104.9	105.4	102.7	102.0	102.5	102.5	103.5	105.1	106.1	107.5	108.1	104.4	100.2	100.2	105.1	152.5
DISTANCE	SIDELINE PERCEIVED NOISE LEVELS																	
152.5 METERS	78.1	88.3	92.0	95.3	94.9	95.2	96.5	96.8	98.0	99.9	100.5	100.6	100.3	94.1	86.9	82.8		

TABLE IV. - Continued. FAR-FIELD NOISE OF QF-9 WITH DESIGN NOZZLE

[Data adjusted to standard day of 15° C and 70 percent relative humidity; SPL re 2×10^{-5} N/m^2; PWL re 10^{-13} W.]

(f) Percent of design speed, 110; fan physical speed, 2380 rpm; fundamental blade-passage frequency, 595 hertz.

FREQUENCY	ANGLE, DEG																AVERAGE SPL	POWER LEVEL (PWL)
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160		
	1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	76.1	75.7	77.6	76.9	76.9	78.7	78.4	79.1	79.7	79.2	80.4	80.5	82.6	84.6	85.2	88.1	81.0	128.4
63	75.7	76.7	75.8	75.8	75.8	76.7	77.0	76.3	77.3	77.7	80.0	80.8	82.7	85.3	86.5	88.9	80.9	128.3
80	80.4	82.5	79.2	77.4	76.7	77.9	78.2	80.0	82.0	83.0	83.9	83.8	85.5	87.2	88.7	90.6	83.6	131.0
100	83.9	84.3	82.6	81.6	81.4	83.1	81.8	83.3	84.3	84.6	86.9	87.4	88.3	89.3	89.8	89.5	85.8	133.2
125	86.7	89.5	89.0	89.2	86.4	89.5	89.2	89.7	91.4	90.5	93.0	92.8	91.9	92.0	90.9	89.1	90.7	138.1
160	88.8	90.4	88.8	86.3	87.8	86.4	87.9	87.6	89.9	90.6	91.6	93.4	91.8	90.3	89.1	89.6	89.9	137.3
200	87.4	89.6	88.1	84.8	84.8	84.3	83.8	84.3	84.4	85.9	86.9	88.4	88.6	88.3	87.3	87.2	86.5	133.9
250	90.5	90.0	89.9	89.0	87.7	89.4	87.5	87.7	89.0	90.5	91.0	92.3	92.5	91.2	89.0	87.8	90.0	137.4
315	90.5	91.9	91.7	90.0	89.2	89.2	89.9	90.5	92.0	93.7	94.0	93.1	93.5	91.2	87.9	86.9	91.7	139.1
400	91.2	93.4	93.0	89.9	90.2	89.5	90.4	91.4	93.0	94.7	95.5	95.8	96.5	93.2	89.4	88.2	93.3	140.7
500	91.8	93.7	93.7	95.5	92.5	93.2	92.7	95.5	96.5	97.3	97.5	98.1	98.3	94.7	91.2	90.6	95.8	143.2
630	98.1	101.2	102.1	105.6	98.6	101.7	99.7	104.1	104.6	105.7	105.2	106.5	106.4	100.7	97.7	97.3	103.9	151.3
800	89.8	91.3	91.1	91.6	91.3	91.0	93.1	94.8	96.8	98.8	99.0	99.5	100.3	97.0	91.8	90.5	96.5	143.9
1000	89.7	91.5	91.6	91.4	90.2	91.0	92.4	93.9	96.5	98.5	99.2	99.5	99.6	95.5	91.2	90.6	96.2	143.6
1250	92.7	94.4	95.4	95.5	93.0	93.4	95.0	95.2	97.7	100.5	101.5	100.6	105.0	97.9	92.4	91.9	99.0	146.4
1600	89.8	90.9	91.3	91.6	90.4	90.9	90.9	92.9	95.1	96.8	98.6	99.9	100.6	94.4	90.3	88.7	95.9	143.3
2000	89.9	91.1	91.6	92.1	91.1	90.6	90.6	92.3	94.8	96.4	98.4	99.0	101.3	94.6	90.6	88.7	95.9	143.3
2500	88.0	89.7	90.2	90.7	89.5	89.2	89.2	90.4	92.9	95.1	96.7	97.7	98.2	92.9	88.5	86.8	94.1	141.5
3150	87.5	88.7	89.0	89.9	88.4	88.9	88.5	89.5	91.9	94.7	96.2	96.5	96.7	92.2	87.9	85.1	93.4	140.8
4000	87.0	88.1	88.6	89.6	88.0	87.5	87.1	88.8	91.3	93.0	94.5	95.4	96.6	92.1	88.1	84.9	92.7	140.1
5000	85.3	86.5	86.5	88.1	85.8	84.5	84.8	86.5	88.8	91.0	93.2	93.0	94.8	89.8	86.3	83.6	91.0	138.4
6300	84.0	85.6	85.1	85.6	83.5	85.5	85.0	84.8	87.8	91.5	93.0	93.8	93.3	91.1	85.3	82.2	91.2	138.6
8000	83.8	85.4	84.8	85.5	82.8	83.9	82.8	84.1	88.3	89.6	91.8	92.0	94.0	89.8	86.2	82.0	91.0	138.4
10000	81.3	83.0	81.7	83.4	79.7	81.9	80.2	82.2	85.5	87.5	89.7	89.9	92.2	88.2	84.0	79.5	89.9	137.3
12500	79.6	81.3	79.8	82.1	78.6	80.4	79.1	81.1	84.6	86.3	88.1	89.1	90.9	86.8	83.8	79.8	90.1	137.5
16000	76.2	78.3	77.2	77.8	74.6	76.5	75.8	77.0	80.7	83.3	85.2	85.7	87.0	84.4	80.0	76.9	88.6	136.0
20000	72.5	74.8	73.7	74.5	70.5	72.8	72.2	74.5	78.2	80.2	81.5	82.6	84.2	81.4	77.5	73.0	88.2	135.6
OVERALL	103.4	105.5	105.9	107.7	103.6	105.0	104.5	107.1	108.5	110.0	110.6	111.3	112.3	107.4	104.0	103.3	108.7	156.1
DISTANCE	SIDELINE-PERCEIVED NOISE LEVELS																	
152.5 METERS	77.9	88.5	93.3	97.6	95.7	98.4	98.5	101.6	103.2	104.6	104.7	104.7	104.4	97.4	91.1	85.9		

(g) Percent of design speed, 115; fan physical speed, 2488 rpm; fundamental blade-passage frequency, 622 hertz.

FREQUENCY	ANGLE, DEG																AVERAGE SPL	POWER LEVEL (PWL)
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160		
	1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	78.8	78.8	79.3	80.3	79.8	80.3	79.7	79.7	80.5	80.2	80.8	81.9	82.5	85.5	87.0	89.4	82.2	129.6
63	76.8	77.8	76.8	76.8	77.0	77.5	77.8	77.2	77.3	79.3	80.3	82.1	83.8	86.2	87.8	89.9	81.9	129.3
80	87.4	87.7	85.4	83.6	84.9	80.2	83.7	80.7	84.1	84.4	83.4	86.3	89.1	90.7	91.2	92.4	86.5	133.9
100	87.5	86.8	84.6	84.5	84.5	83.3	83.0	83.6	84.1	86.0	87.3	87.6	88.8	90.3	90.5	90.7	86.7	134.1
125	94.9	95.1	91.9	92.7	90.9	87.2	90.1	88.7	90.7	91.9	94.2	93.2	92.4	92.9	92.1	89.6	91.9	139.3
160	92.0	93.0	90.5	89.0	89.3	88.3	89.0	89.5	92.1	91.6	93.3	94.7	93.8	92.0	90.6	90.0	91.6	139.0
200	91.3	93.5	91.2	86.8	86.8	86.0	85.5	86.5	86.8	87.5	89.5	90.6	91.3	90.3	89.2	88.7	88.9	136.3
250	92.5	93.7	91.8	91.2	90.2	89.2	88.8	88.7	90.2	91.8	93.3	94.9	95.2	93.8	90.3	89.4	92.0	139.4
315	93.1	93.5	92.3	92.5	91.1	91.5	91.8	93.0	93.5	94.5	95.3	95.4	94.5	93.1	90.1	89.0	93.3	140.7
400	92.2	93.7	93.4	92.7	92.2	91.9	92.0	93.9	95.2	96.9	98.5	99.3	98.9	96.2	91.4	90.8	95.8	143.2
500	91.7	93.6	93.4	93.7	93.4	92.7	94.1	96.1	98.1	99.2	99.1	99.2	99.9	95.9	91.9	91.4	96.9	144.3
630	97.1	100.3	97.3	100.3	96.4	99.4	101.4	106.8	109.1	109.9	106.6	106.4	110.1	102.1	97.8	95.2	106.0	153.4
800	91.2	92.2	92.5	93.7	93.2	92.8	95.2	97.2	99.2	101.3	101.2	101.3	102.2	98.8	93.8	92.4	98.6	146.0
1000	90.5	92.4	92.3	93.4	91.7	92.4	94.4	96.2	98.2	99.7	101.0	101.3	101.7	97.2	93.0	92.4	97.9	145.3
1250	92.1	95.8	96.6	97.3	94.9	94.4	95.4	97.6	99.3	102.3	102.3	104.9	103.3	99.1	95.1	93.8	100.2	147.6
1600	90.4	91.7	91.5	92.4	92.2	91.9	92.4	95.0	97.0	98.5	100.0	101.8	102.4	96.5	92.5	90.8	97.6	145.0
2000	91.8	93.0	93.1	94.1	93.5	93.0	93.0	94.3	97.0	99.0	100.8	101.2	102.8	97.0	93.3	91.5	98.0	145.4
2500	89.1	90.9	90.8	91.9	90.6	90.6	90.9	92.4	94.9	97.3	98.8	99.7	100.4	94.9	90.8	88.9	96.1	143.5
3150	87.8	90.3	89.8	91.0	89.5	90.0	90.6	91.5	94.1	96.8	98.3	99.1	99.3	95.0	90.0	87.7	95.6	143.0
4000	87.6	89.6	89.6	91.1	89.4	89.1	88.6	91.1	93.6	94.9	96.8	97.9	99.5	94.8	90.1	87.2	95.0	142.4
5000	85.7	87.4	87.1	89.1	86.9	86.1	86.7	88.4	91.7	93.2	95.4	95.7	97.7	92.2	89.1	86.1	93.4	140.8
6300	84.5	86.7	85.3	86.8	84.7	87.0	86.6	86.8	90.1	93.7	95.5	96.5	96.7	93.8	87.7	84.3	93.7	141.1
8000	84.5	86.3	85.3	86.5	84.0	85.2	85.2	86.2	90.5	92.2	94.3	94.9	97.1	92.8	88.6	84.9	93.6	141.0
10000	81.6	84.1	82.2	83.9	80.9	83.1	82.4	83.9	87.9	89.6	92.3	93.0	95.3	91.1	86.8	82.2	92.5	139.9
12500	80.2	82.7	80.2	82.9	79.7	81.7	81.0	83.2	86.9	88.5	90.9	91.8	94.2	89.4	86.4	82.4	92.7	140.1
16000	76.4	79.0	77.6	78.5	75.8	77.5	77.4	78.9	83.4	85.4	87.7	88.2	89.7	87.2	82.4	79.3	91.0	138.4
20000	72.9	75.5	73.5	74.9	71.5	73.8	74.0	76.6	81.0	82.5	84.0	84.9	86.9	84.0	79.9	75.3	90.6	138.0
OVERALL	104.7	106.5	105.3	106.3	104.6	104.9	106.1	109.4	111.6	112.9	112.3	113.0	114.4	109.3	105.6	104.3	110.7	158.1
DISTANCE	SIDELINE PERCEIVED NOISE LEVELS																	
152.5 METERS	78.6	89.2	92.6	96.3	97.2	98.4	100.3	103.8	106.2	107.5	106.8	106.6	106.5	99.6	92.9	86.6		

TABLE IV. - Concluded. FAR-FIELD NOISE OF QF-9 WITH DESIGN NOZZLE

[Data adjusted to standard day of 15° C and 70 percent relative humidity; SPL re 2×10^{-5} N/m^2; PWL re 10^{-13} W.]

(h) Percent of design speed, 120; fan physical speed, 2596 rpm; fundamental blade-passage frequency, 649 hertz.

FREQUENCY	ANGLE, DEG																AVERAGE SPL	POWER LEVEL (PWL)
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160		
	1/3-OCTAVE BAND SOUND PRESSURE LEVEL (SPL) ON 30.5-METER RADIUS																	
50	82.3	82.3	82.3	84.3	80.0	84.3	84.3	82.6	84.5	85.6	81.8	84.1	84.6	88.5	88.0	90.7	84.9	132.3
63	77.7	78.8	78.2	77.7	77.2	77.3	78.5	78.5	78.8	79.5	80.3	82.4	84.8	87.2	88.7	90.9	82.7	130.1
80	85.8	87.3	88.9	85.6	83.1	81.4	79.4	82.1	81.9	82.4	85.4	87.0	90.4	90.8	90.9	93.7	86.9	134.3
100	89.3	88.8	88.6	87.3	85.9	85.1	85.1	85.4	85.3	86.9	88.4	89.2	90.4	91.7	90.9	91.6	88.2	135.6
125	92.9	94.9	94.3	94.6	90.8	89.4	90.4	91.4	91.6	92.4	93.6	94.2	94.8	94.1	92.4	91.0	92.8	140.2
160	93.0	94.1	92.8	91.3	90.3	90.6	91.0	91.3	92.3	93.3	94.0	95.6	94.1	93.3	90.8	90.3	92.7	140.1
200	93.5	96.7	93.5	89.5	89.2	88.2	87.0	88.8	88.5	90.0	91.0	92.1	92.5	91.7	90.2	90.4	90.8	138.2
250	94.1	95.0	93.6	93.3	92.3	90.8	89.8	91.1	92.8	94.5	96.1	96.9	97.0	95.0	91.3	90.2	94.0	141.4
315	94.2	95.2	95.4	94.5	93.0	93.0	93.2	94.4	95.0	96.7	97.2	97.8	97.2	95.0	91.7	90.2	95.3	142.7
400	94.3	94.9	95.6	94.6	94.4	93.9	93.8	95.4	97.4	99.8	101.1	101.9	101.1	97.8	93.6	91.8	98.1	145.5
500	93.8	94.6	95.1	95.4	94.6	94.8	95.9	97.8	98.9	100.3	100.6	101.5	100.9	97.4	93.9	92.8	98.4	145.8
630	97.0	103.0	101.0	101.6	100.6	99.6	104.8	107.6	108.8	108.3	105.5	109.6	110.8	105.1	102.6	96.5	106.6	154.0
800	92.6	94.7	95.2	95.4	95.6	95.2	97.9	100.0	101.5	102.7	102.9	103.6	104.4	100.7	96.2	94.6	100.7	148.1
1000	91.5	93.9	95.0	95.1	94.4	95.2	96.4	98.4	100.2	101.6	102.7	103.2	103.9	99.1	95.1	94.1	99.9	147.3
1250	96.6	96.6	99.2	97.6	97.4	96.9	97.9	100.2	101.2	102.7	104.1	104.3	105.2	101.4	96.4	95.5	101.5	148.9
1600	91.7	92.9	94.0	93.7	93.5	93.7	94.7	96.9	99.2	100.5	101.9	103.5	104.9	98.5	94.2	92.4	99.6	147.0
2000	92.7	94.8	95.0	95.3	94.3	94.5	94.7	95.8	98.8	100.7	102.3	103.1	104.7	98.5	94.5	92.4	99.7	147.1
2500	90.1	92.1	92.6	93.6	92.0	91.8	92.8	94.3	96.8	99.3	100.6	101.7	102.5	96.6	92.6	90.4	98.0	145.4
3150	89.6	91.3	91.8	92.1	91.1	91.9	92.4	93.6	95.9	98.9	100.3	101.2	101.4	96.8	92.1	89.2	97.6	145.0
4000	89.0	91.2	91.4	92.1	91.2	91.2	90.5	93.0	95.6	97.2	99.0	100.4	101.9	96.7	91.9	89.0	97.2	144.6
5000	87.1	88.6	89.0	91.1	88.6	88.5	88.5	91.0	94.0	95.3	98.2	98.2	100.7	94.7	91.2	88.3	95.9	143.3
6300	85.8	87.8	87.8	88.6	86.5	89.0	89.2	89.2	92.5	95.8	98.0	98.9	99.2	96.5	90.3	86.7	96.1	143.5
8000	85.5	87.7	87.2	88.0	85.7	87.5	87.2	89.0	92.9	94.3	96.7	97.2	99.8	95.3	91.3	86.9	96.0	143.4
10000	83.0	85.2	84.1	85.7	83.0	85.7	84.5	86.7	90.3	92.0	94.8	95.6	97.8	93.7	89.5	84.6	95.0	142.4
12500	81.1	83.6	82.3	84.4	81.6	84.3	83.3	85.6	89.3	91.0	93.3	94.4	96.8	92.1	88.8	84.7	95.2	142.6
16000	77.5	80.4	79.7	79.9	77.4	80.2	80.0	81.4	85.2	87.4	90.2	91.0	92.9	89.7	85.4	81.6	93.6	141.0
20000	74.1	76.6	75.4	76.2	73.6	76.4	76.4	79.0	82.6	84.4	86.2	88.0	89.7	86.6	82.9	77.5	93.1	140.5
OVERALL	105.9	108.2	107.9	107.7	106.8	106.5	108.6	110.9	112.4	113.2	113.6	115.1	116.0	111.4	107.9	105.7	112.2	159.6
DISTANCE	SIDELINE PERCEIVED NOISE LEVELS																	
152.5 METERS	79.4	91.2	94.9	97.8	98.7	100.1	102.7	105.4	107.2	107.9	108.4	108.6	108.3	101.5	95.3	87.9		

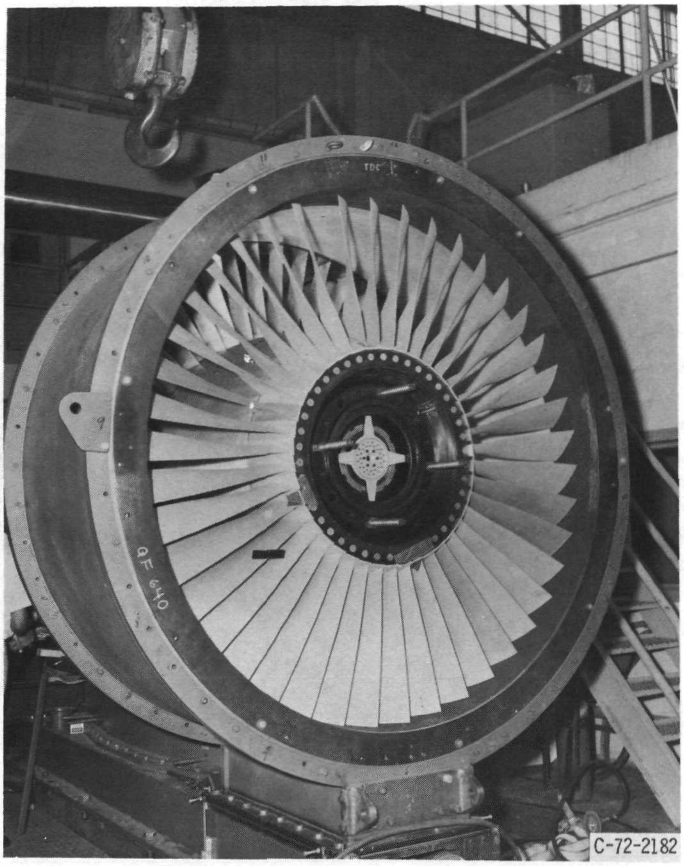


Figure 1. - View of QF-6 rotor blading.

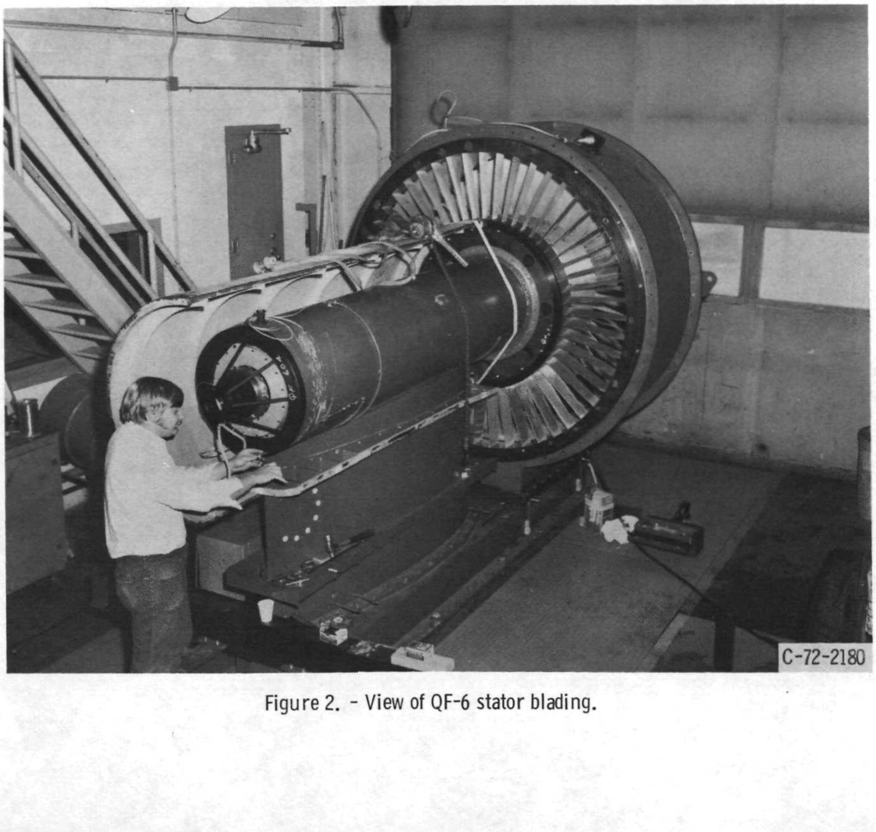


Figure 2. - View of QF-6 stator blading.

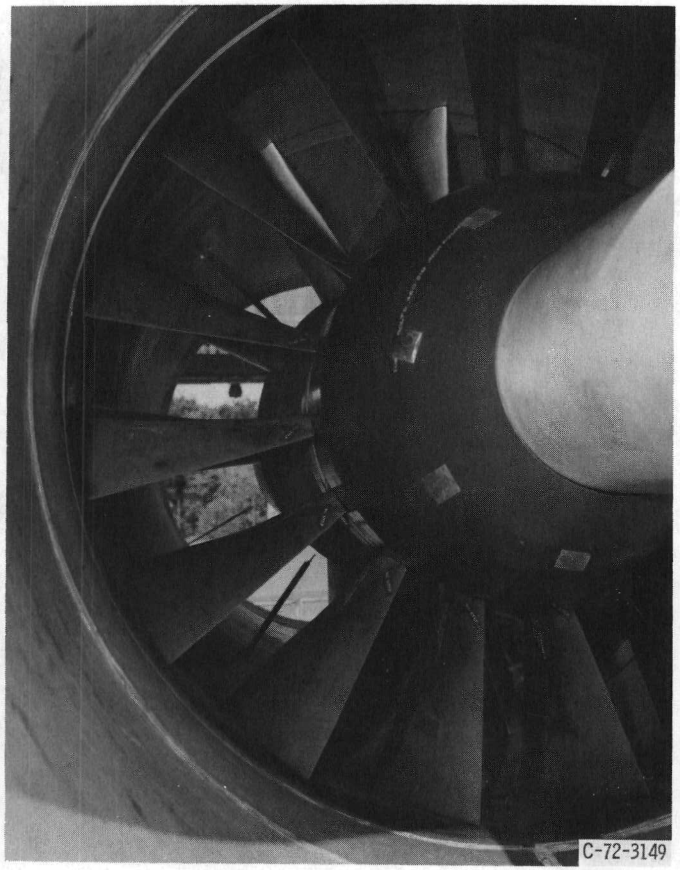


Figure 3. - View of QF-9 rotor blading.

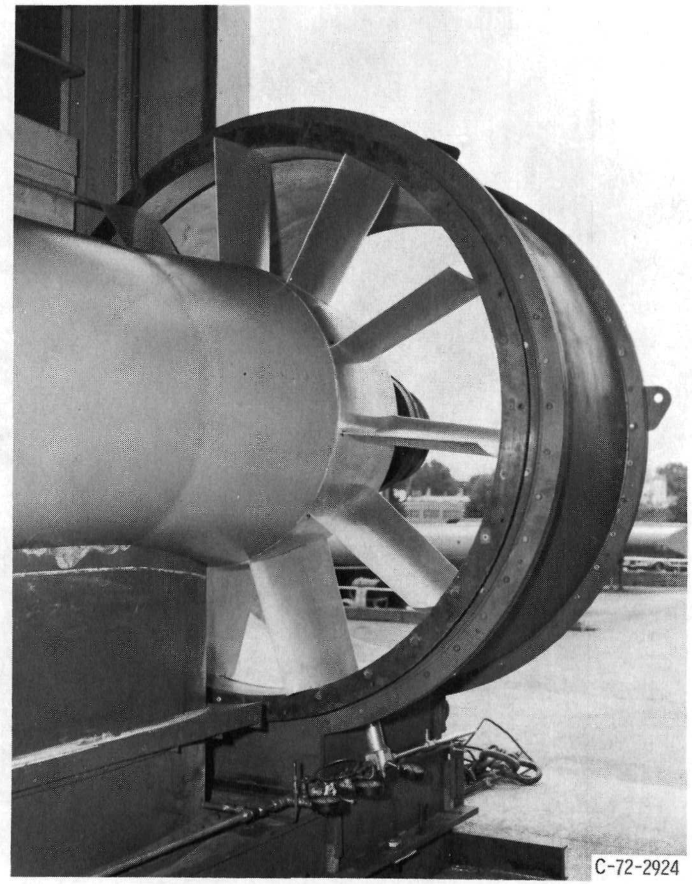
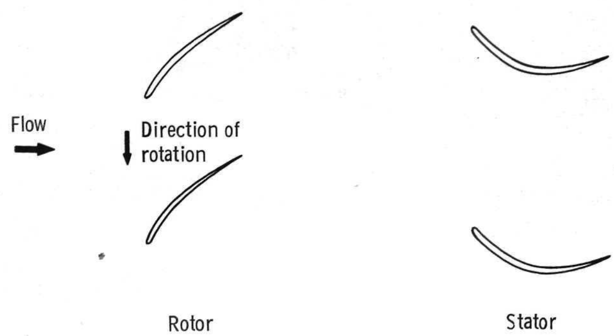
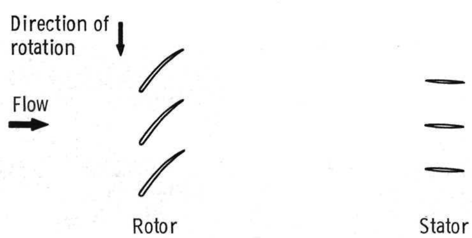


Figure 4. - View of QF-9 stator blading.



(a) QF-9.



(b) QF-6.

Figure 5. - Relative blade positions for QF-6 and QF-9. All cross sections at tip location viewed inward toward hub.

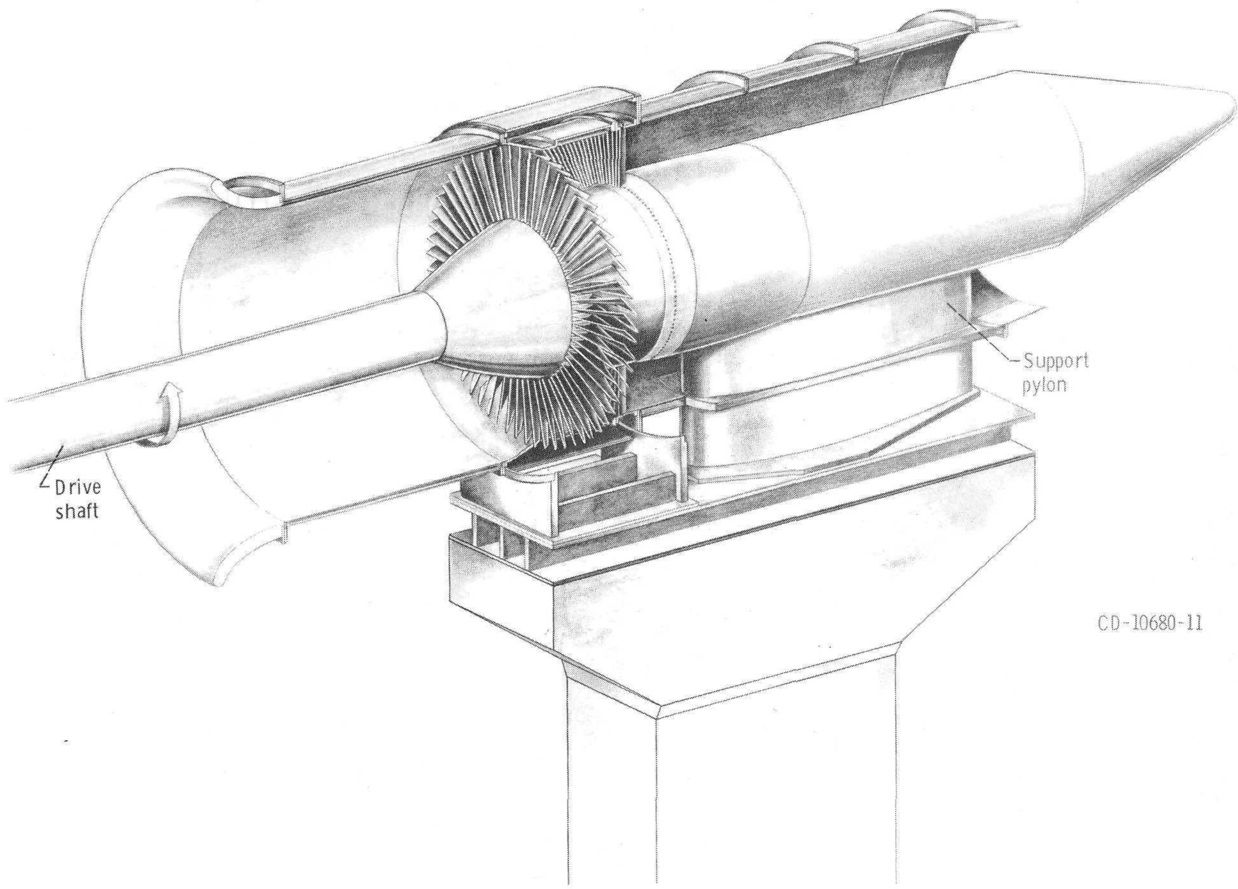


Figure 6. - Cutaway sketch of typical fan installation.

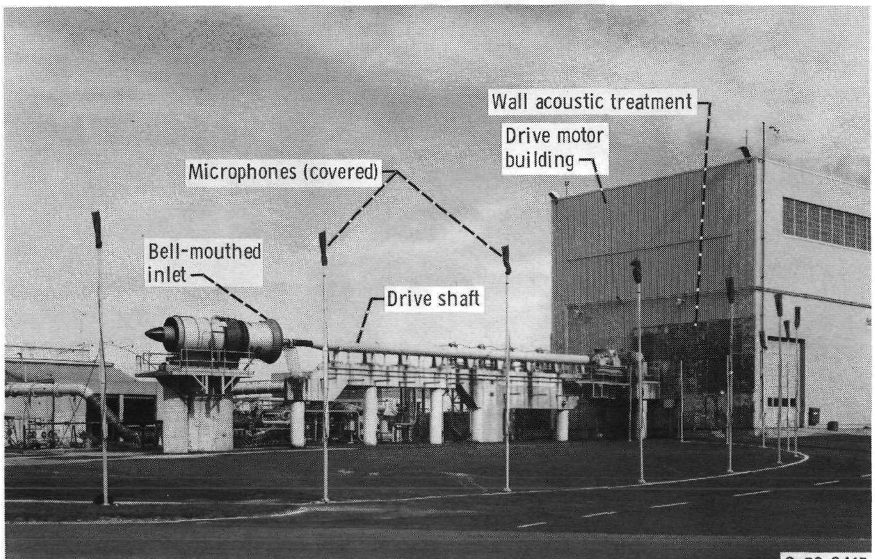


Figure 7. - Test site showing QF-9 in place.

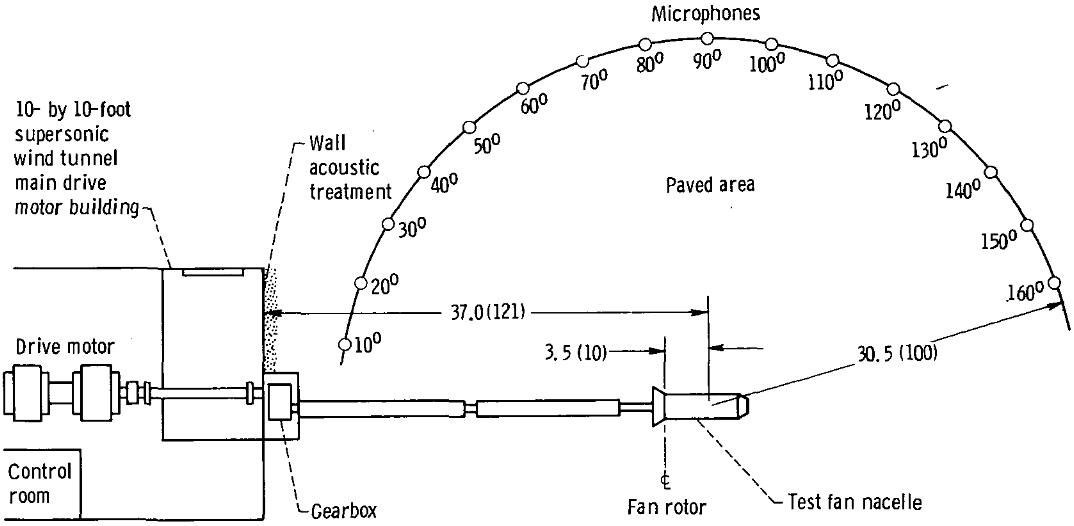


Figure 8. - Plan view of quiet-fan acoustic test facility. (All dimensions are in m (ft).)

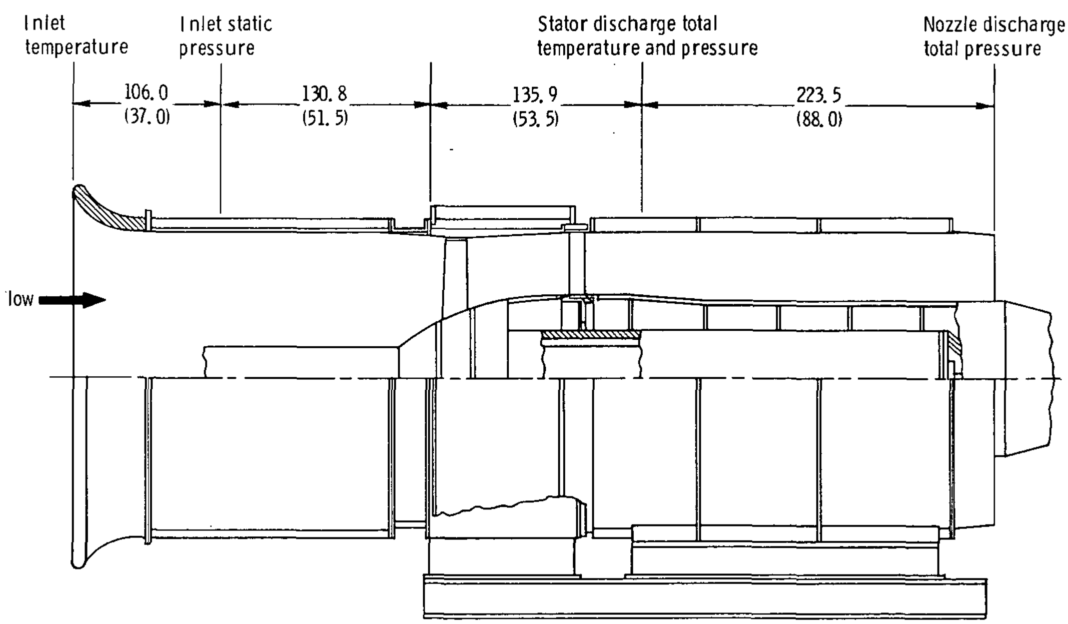


Figure 9. - Cross section of QF-6 fan stage (hard walls). (All dimensions are in cm (in.).)

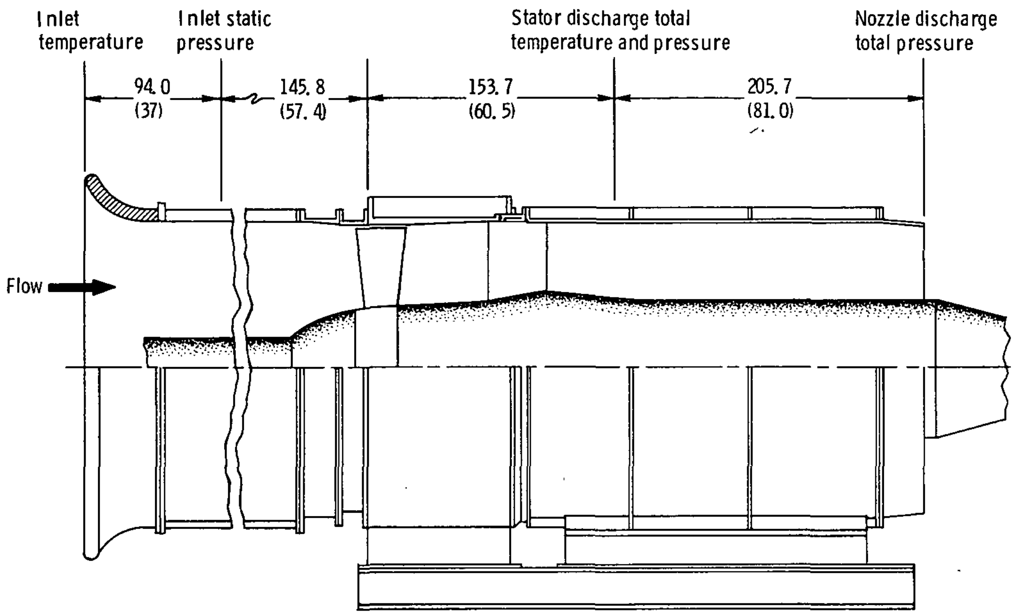


Figure 10. - Cross section of QF-9 stage (hard walls). (All dimensions are in cm (in.).)

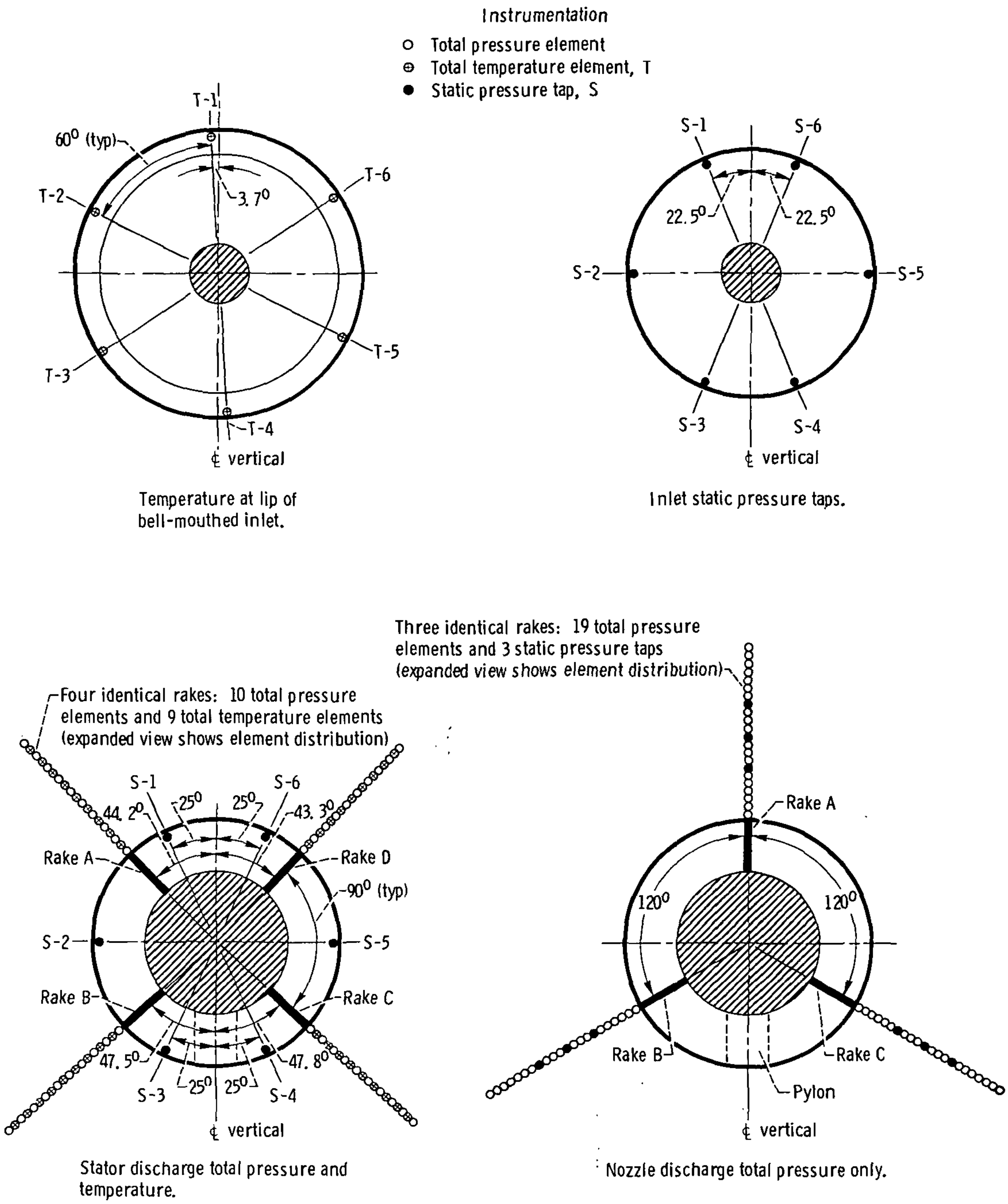


Figure 11. - Detail of fan aerodynamic instrumentation. All views looking downstream. Instrumentation common for QF-9 and QF-6.

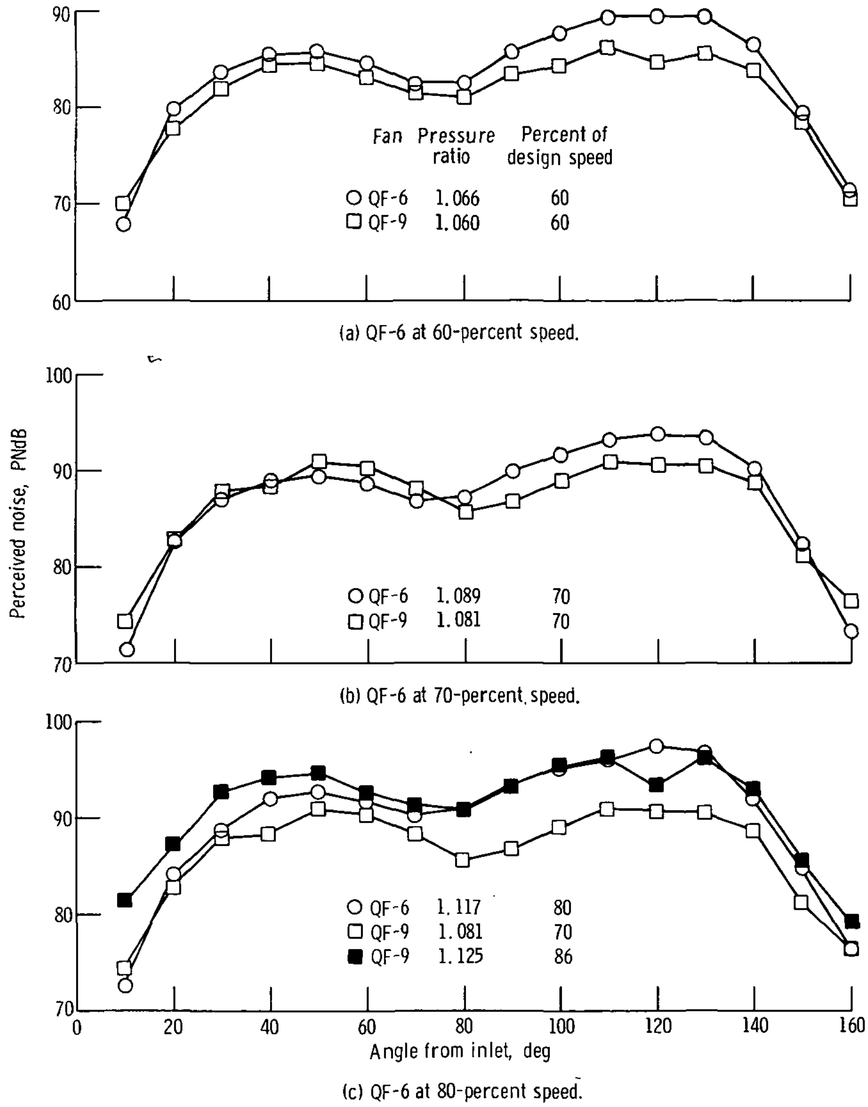
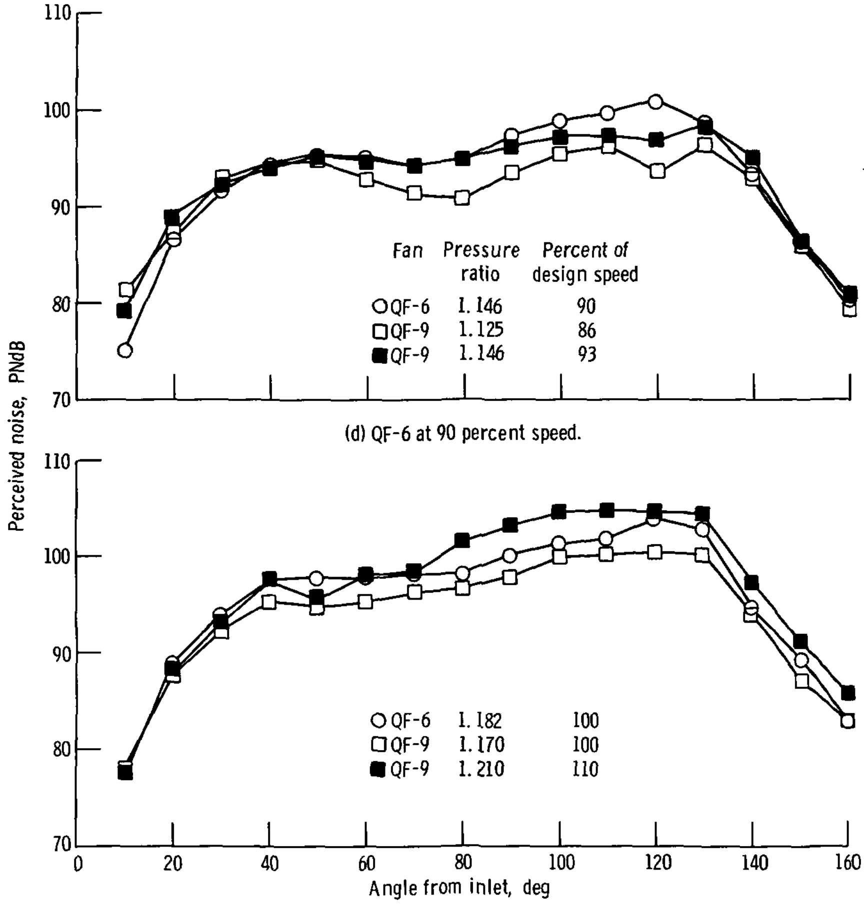


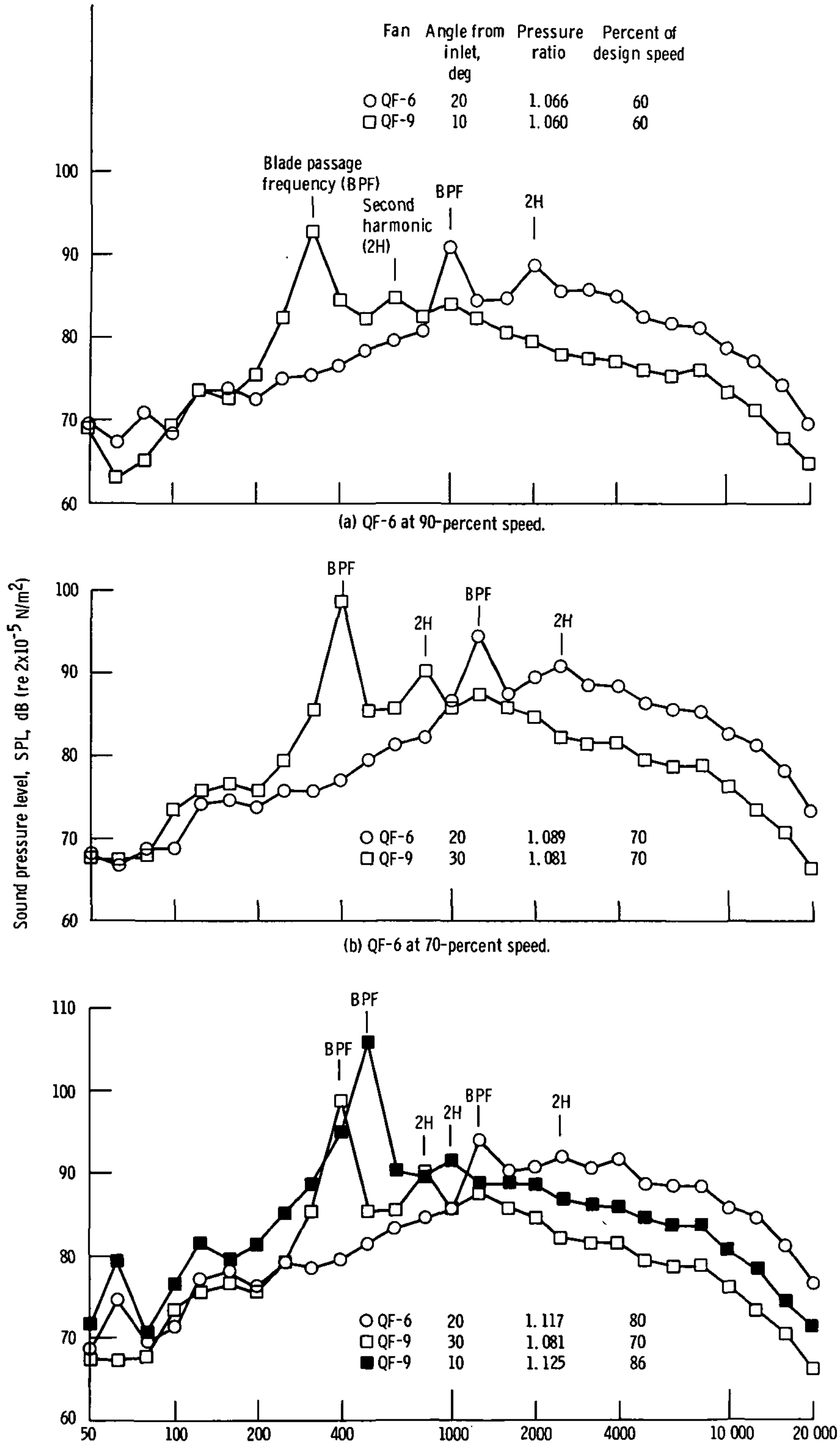
Figure 12. - Perceived noise on a 152.5-meter (500-ft) sideline.



(d) QF-6 at 90 percent speed.

(e) QF-6 at 100-percent speed.

Figure 12. - Concluded.

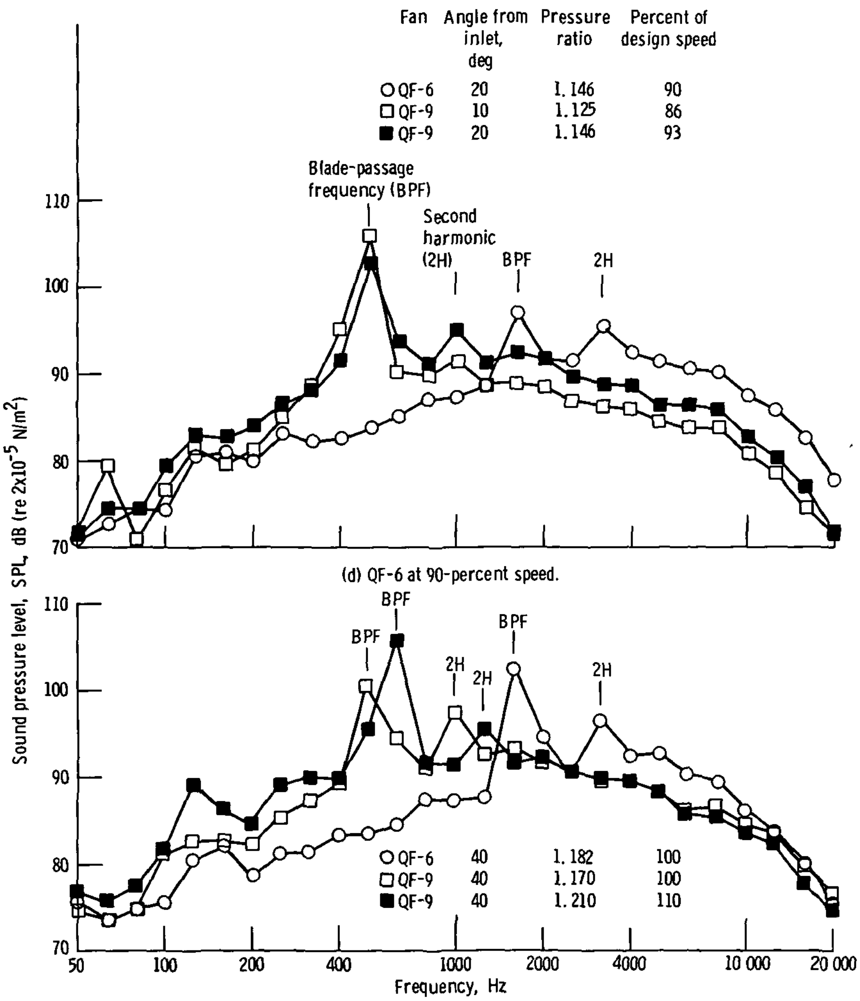


(a) QF-6 at 90-percent speed.

(b) QF-6 at 70-percent speed.

(c) QF-6 at 80-percent speed.

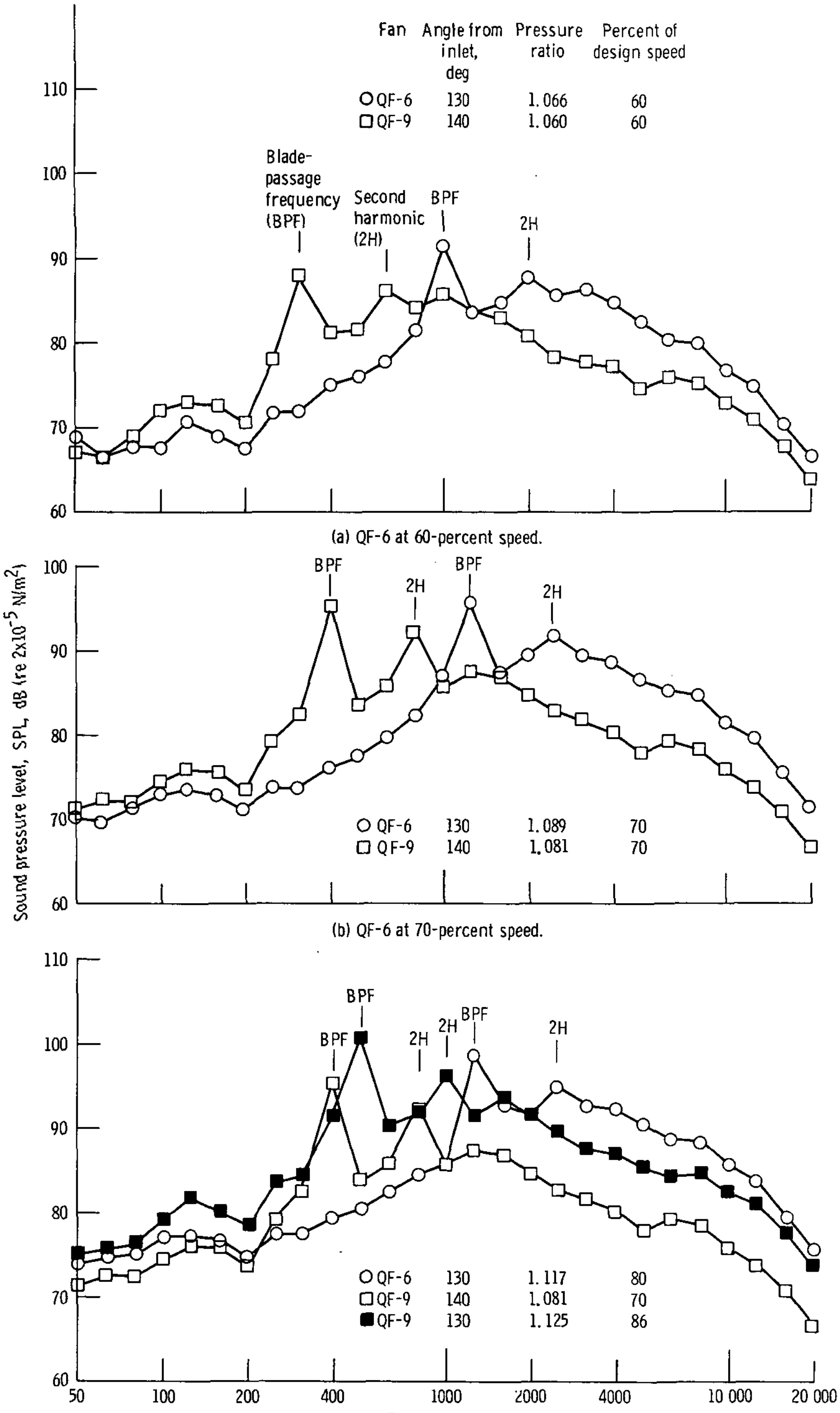
Figure 13. - Sound pressure level at maximum-intensity angle on a 30.5-meter (100-ft) radius - front-quadrant 1/3-octave spectra.



(d) QF-6 at 90-percent speed.

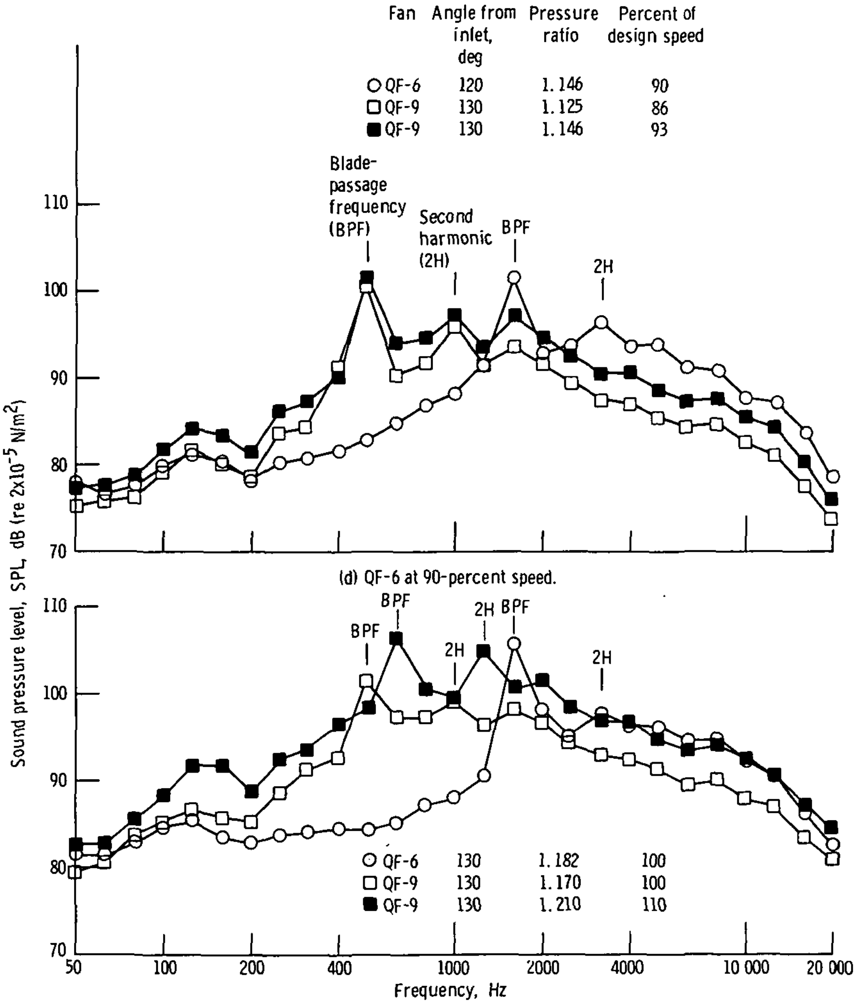
(e) QF-6 at 100-percent speed.

Figure 13. - Concluded.



(c) QF-6 at 80-percent speed.

Figure 14. - Sound pressure level at maximum-intensity angle on a 30.5-meter (100-ft) radius - rear-quadrant 1/3-octave spectra.



(e) QF-6 at 100-percent speed.

Figure 14. - Concluded.

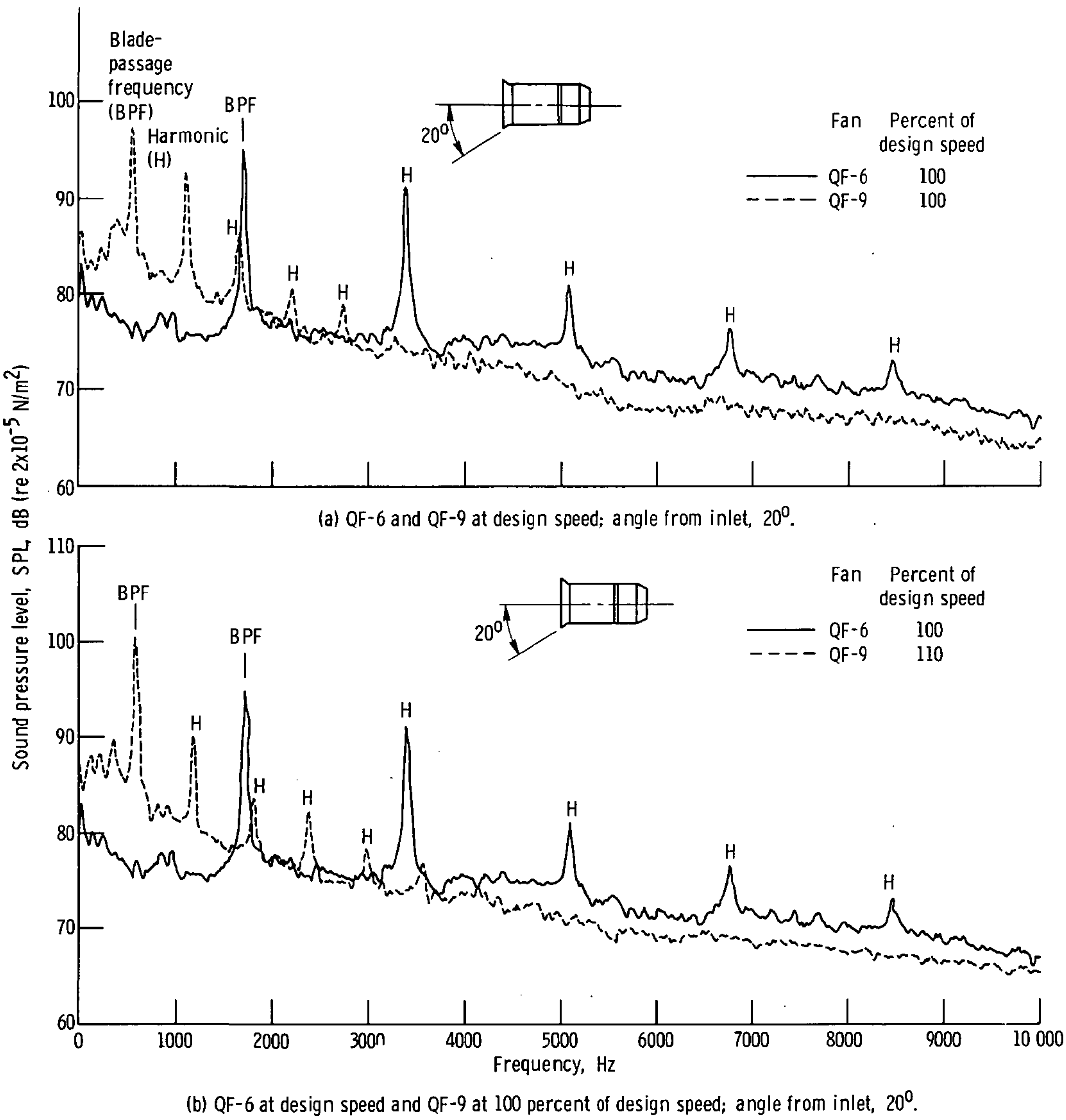
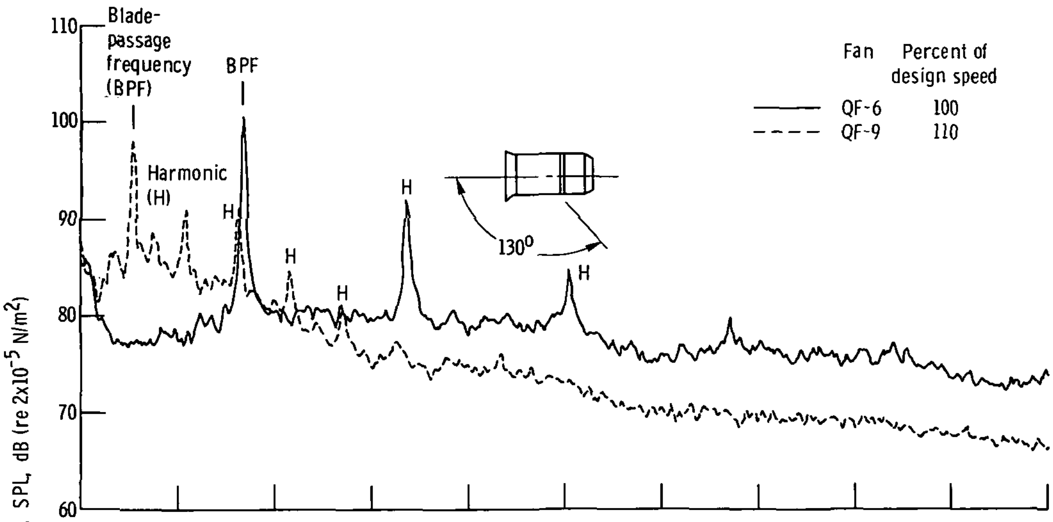
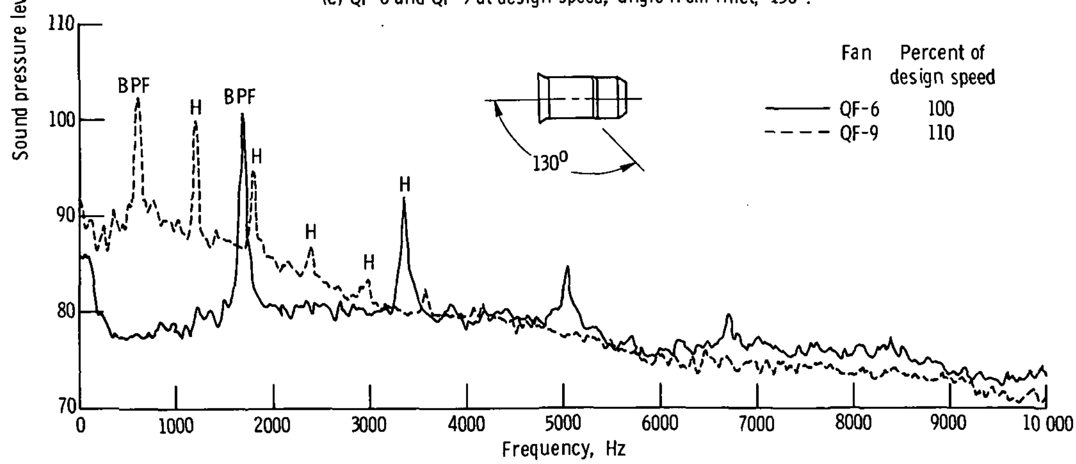


Figure 15. - Comparison of QF-6 and QF-9 narrow-band spectra. Bandwidth, 32 hertz; both fans in design configuration.

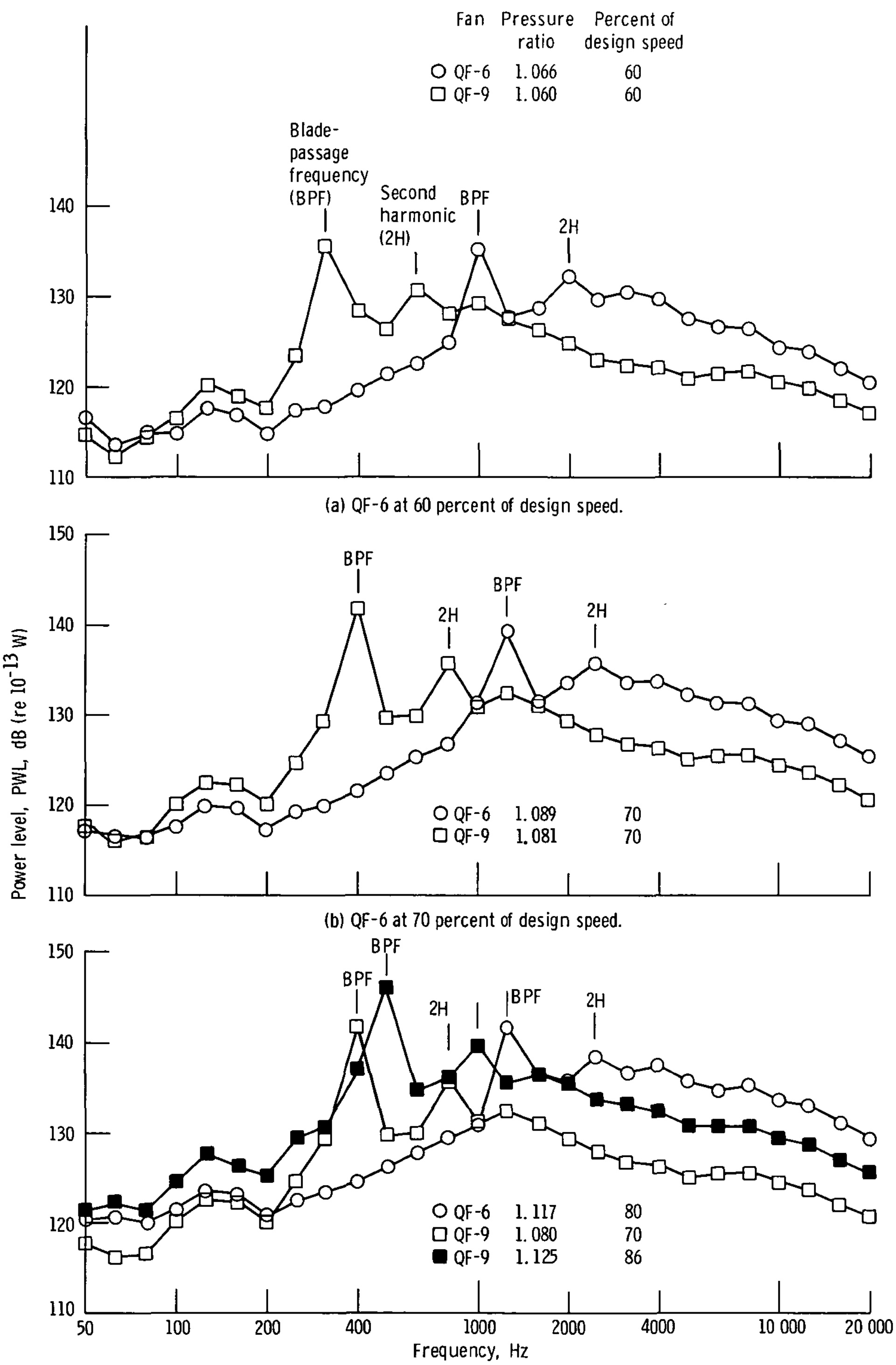


(c) QF-6 and QF-9 at design speed; angle from inlet, 130°.



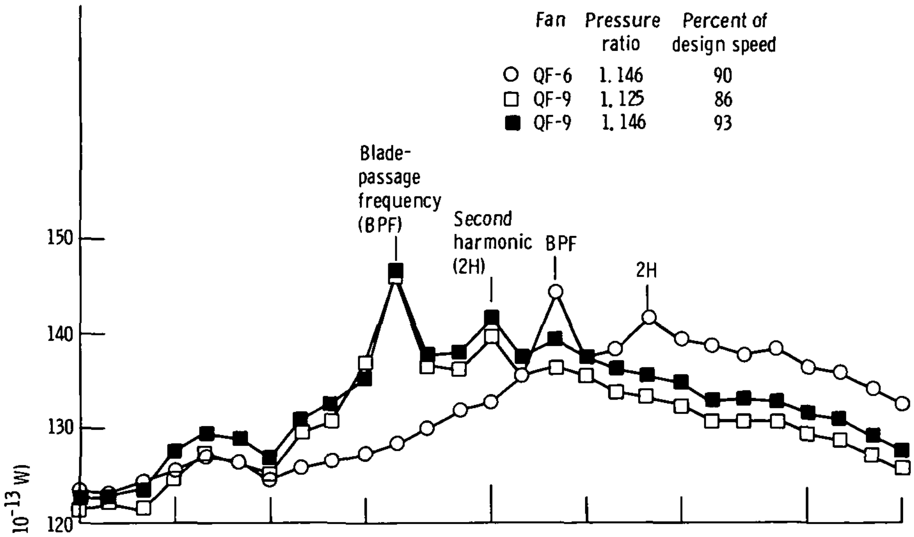
(d) QF-6 at design speed and QF-9 at 110 percent of design speed; angle from inlet, 130°.

Figure 15. - Concluded.

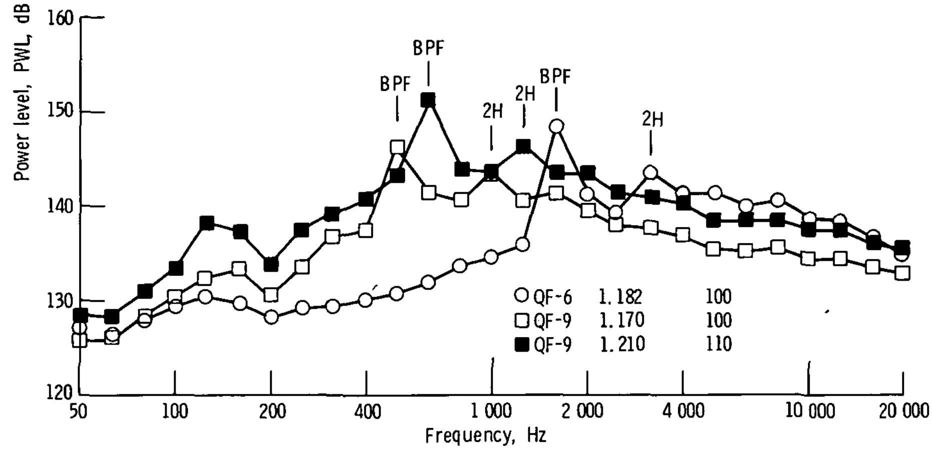


(c) QF-6 at 80 percent of design speed.

Figure 16. - Power level comparison - 1/3-octave spectra.



(d) QF-6 at 90 percent of design speed.



(e) QF-6 at design speed.

Figure 16. - Concluded.

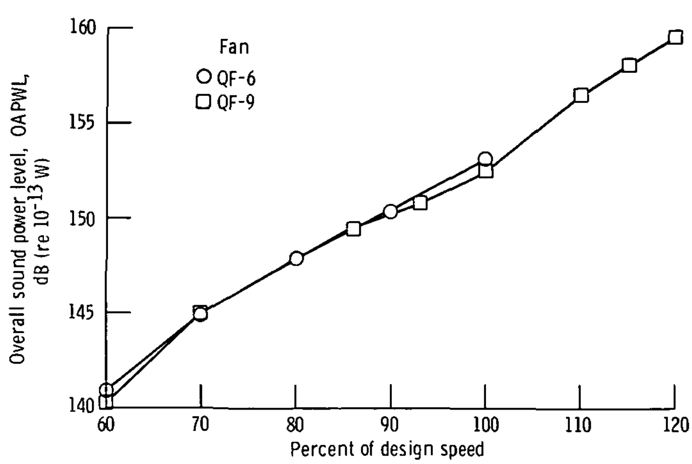


Figure 17. - Overall power level as function of percent of design speed.

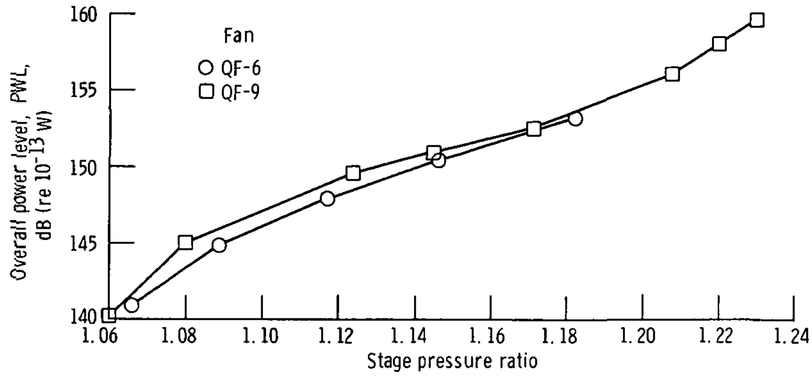


Figure 18. - Overall power level as function of stage pressure ratio.

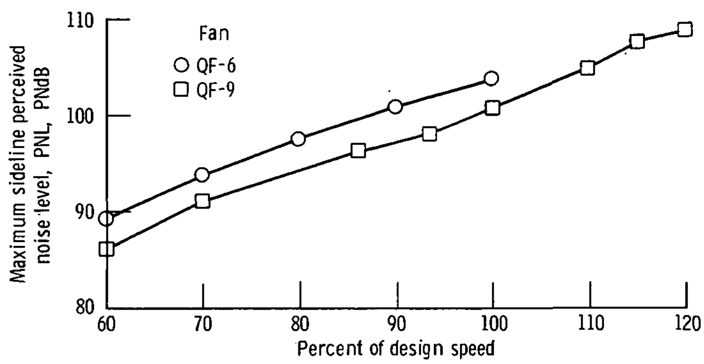


Figure 19. - Maximum perceived noise level on 152.5-meter (500-ft) sideline as function of percent of design speed.

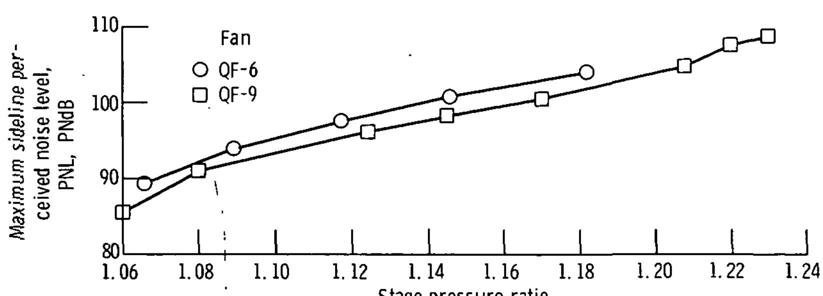
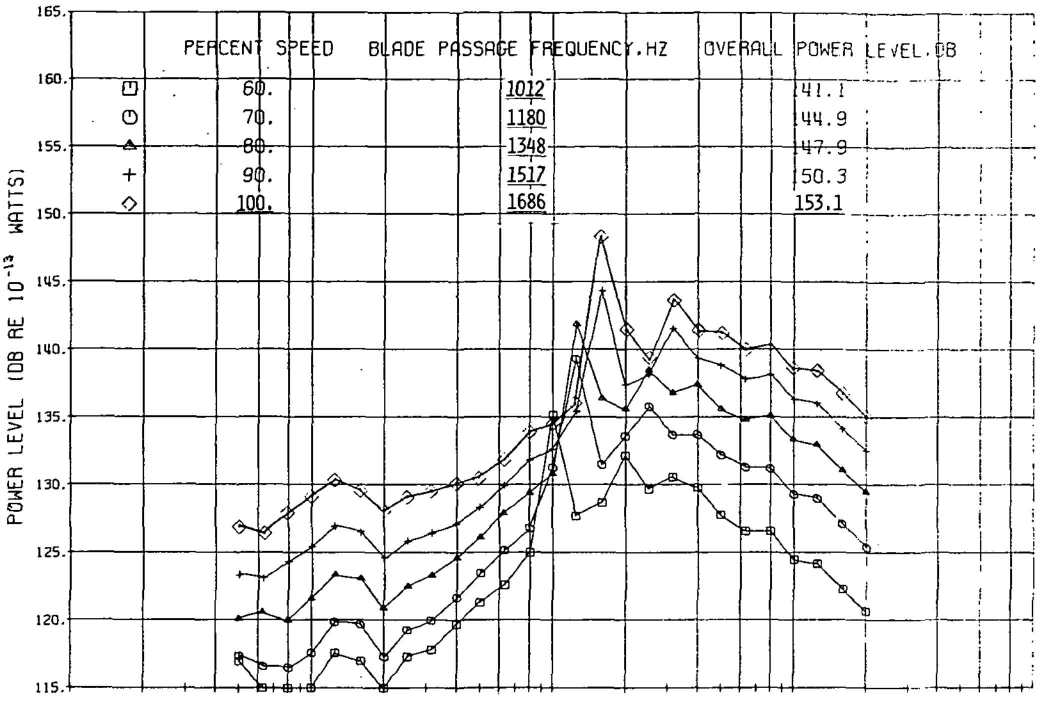
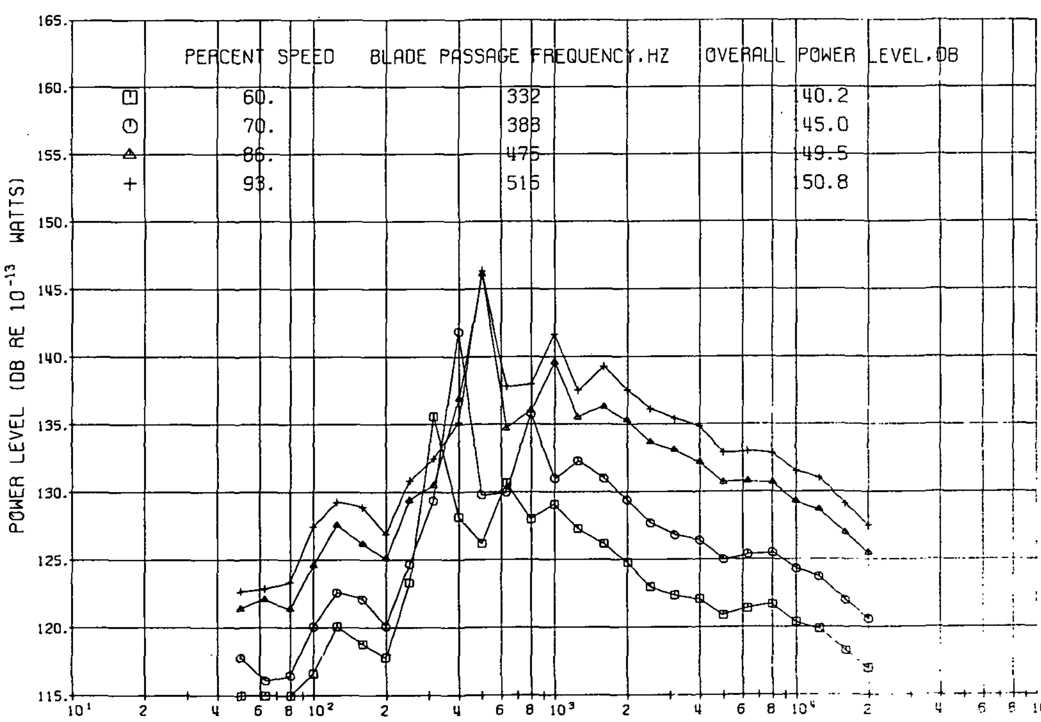


Figure 20. - Maximum perceived noise level on 152.5-meter (500-ft) sideline as function of stage pressure ratio.

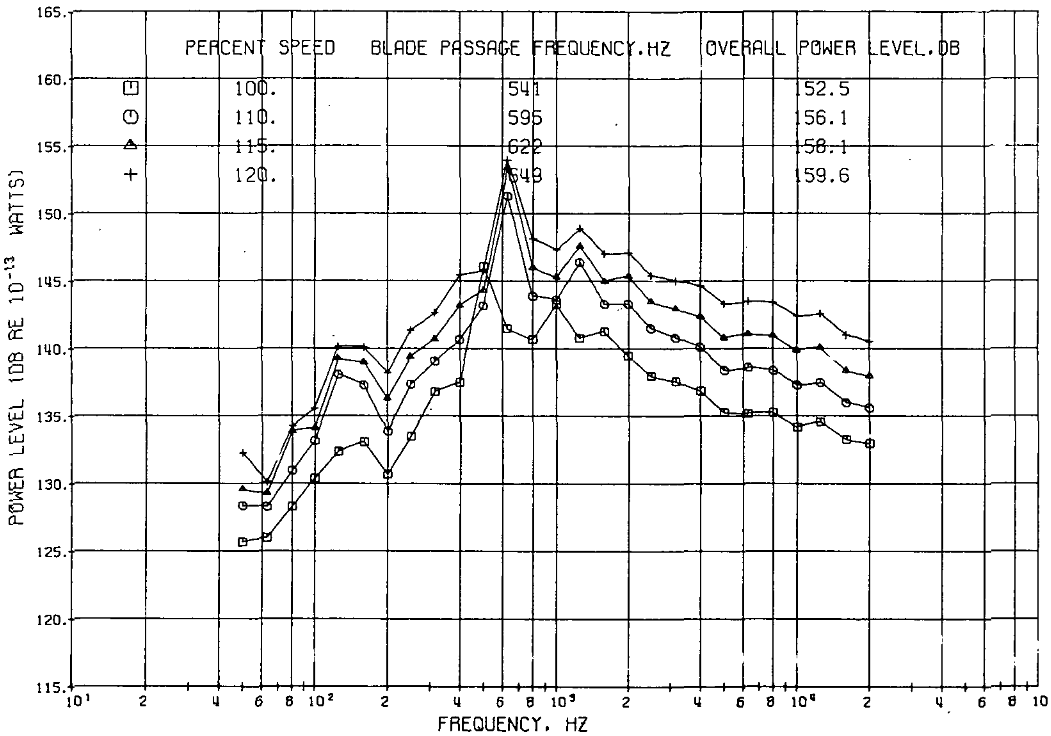


(a) QF-6 at 60, 70, 80, 90, and 100 percent of design speed.



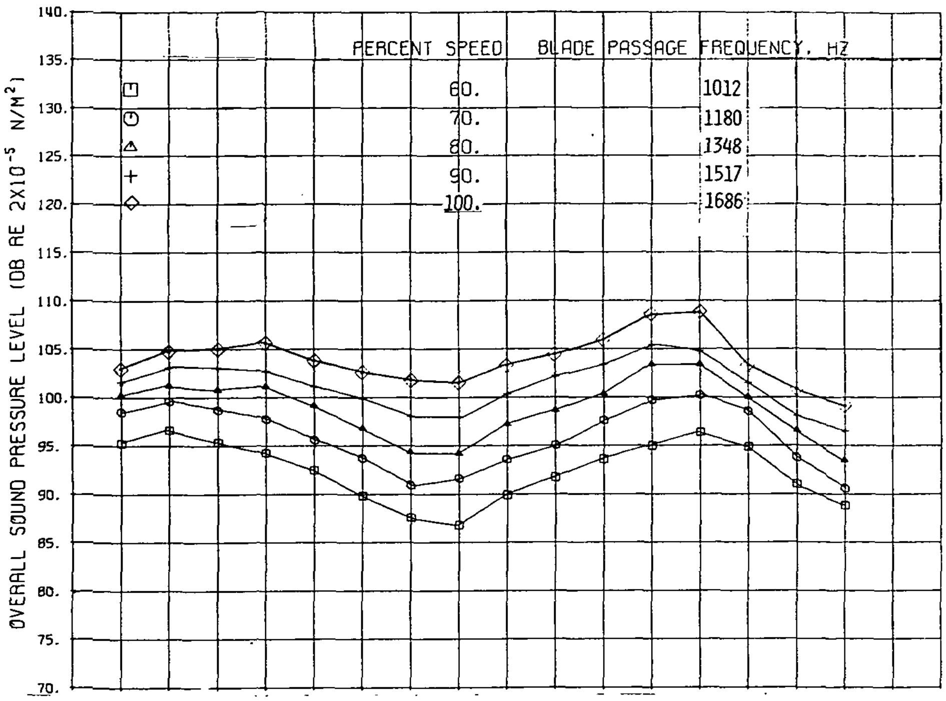
(b) QF-9 at 60, 70, 86, and 93 percent of design speed.

Figure 21. - Comparison of power spectra for QF-6 and QF-9 at various speeds.

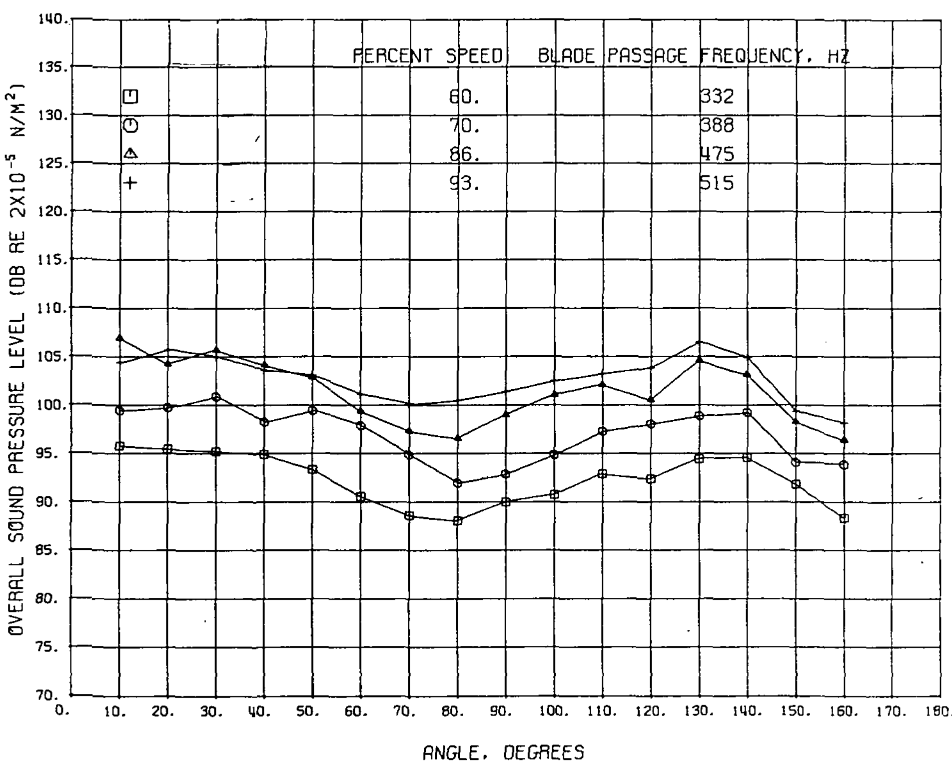


(c) QF-9 at 100, 110, 115, and 120 percent of design speed.

Figure 21. - Concluded.

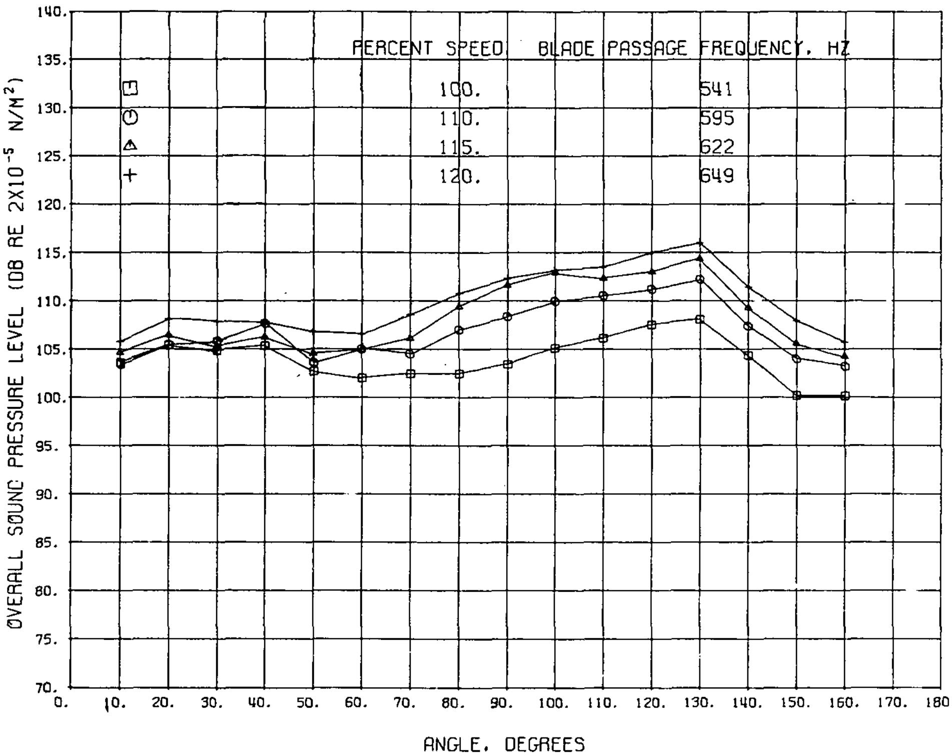


(a) QF-6 at 60, 70, 80, 90, and 100 percent of design speed.



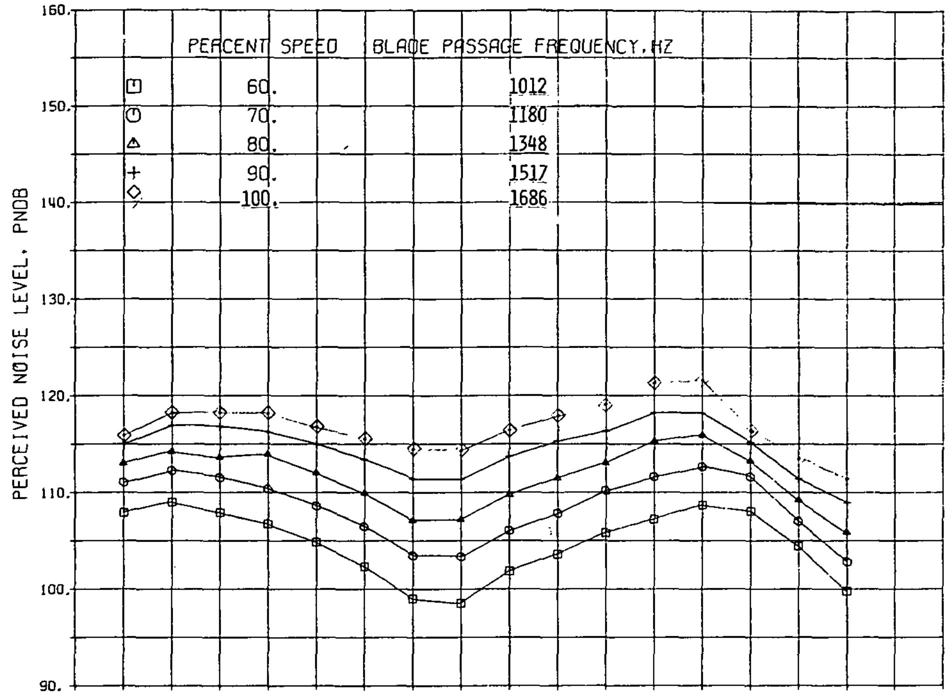
(b) QF-9 at 60, 70, 86, and 93 percent of design speed.

Figure 22. - Overall sound pressure level as function of angle on 30.5-meter radius.

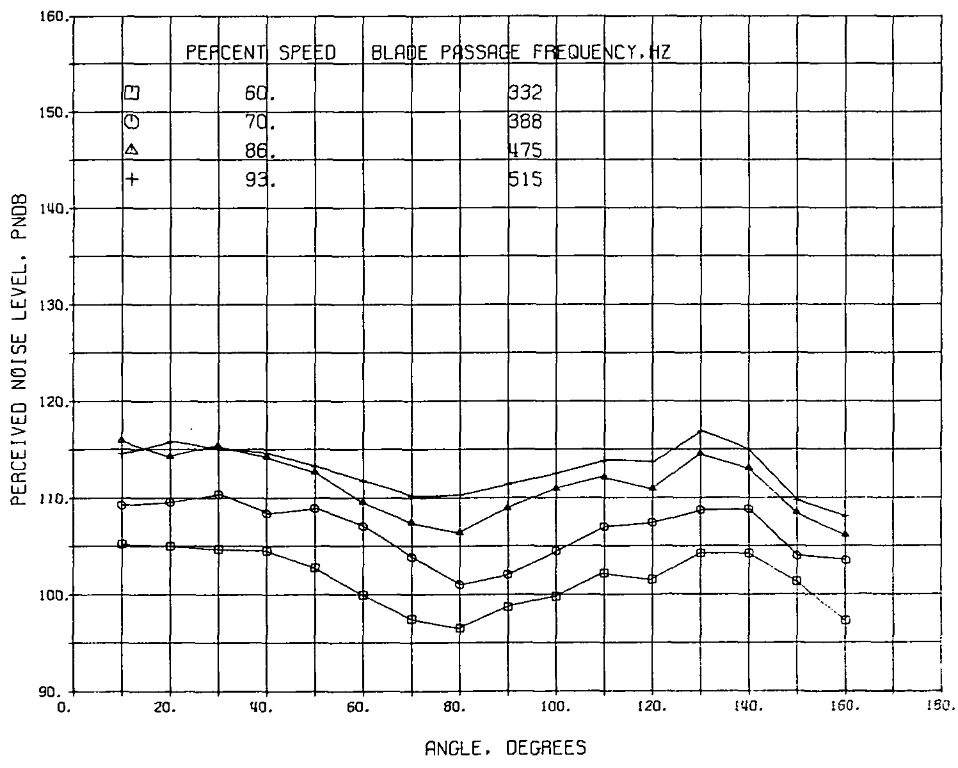


(c) QF-9 at 100, 110, 115, and 120 percent of design speed.

Figure 22. - Concluded.

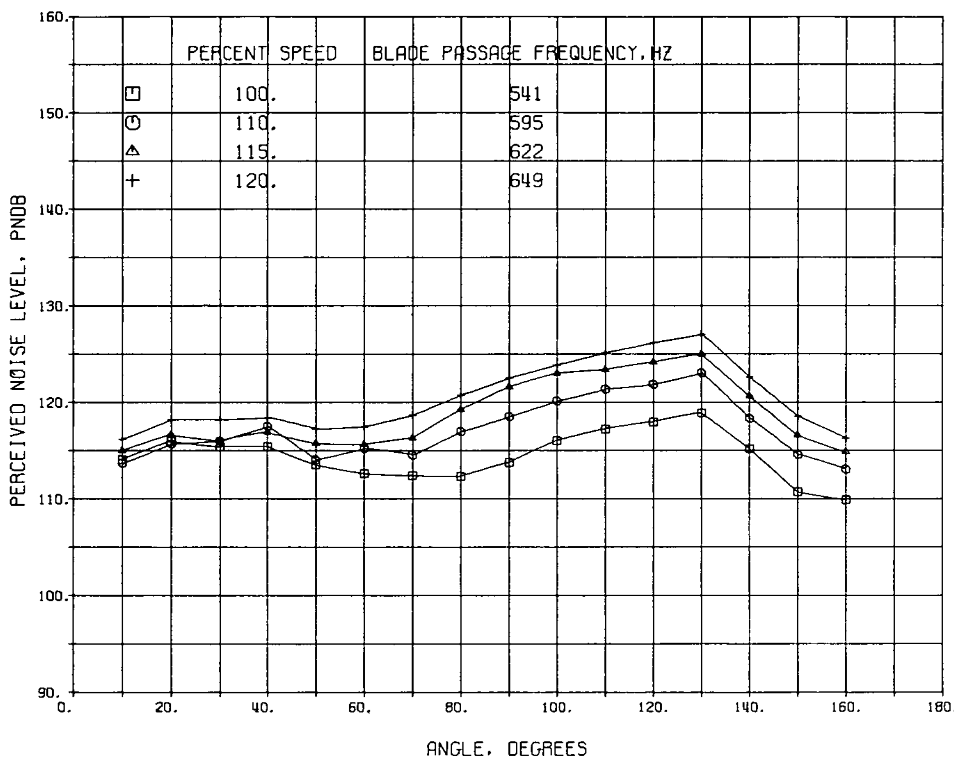


(a) QF-6 at 60, 70, 80, 90, and 100 percent of design speed.



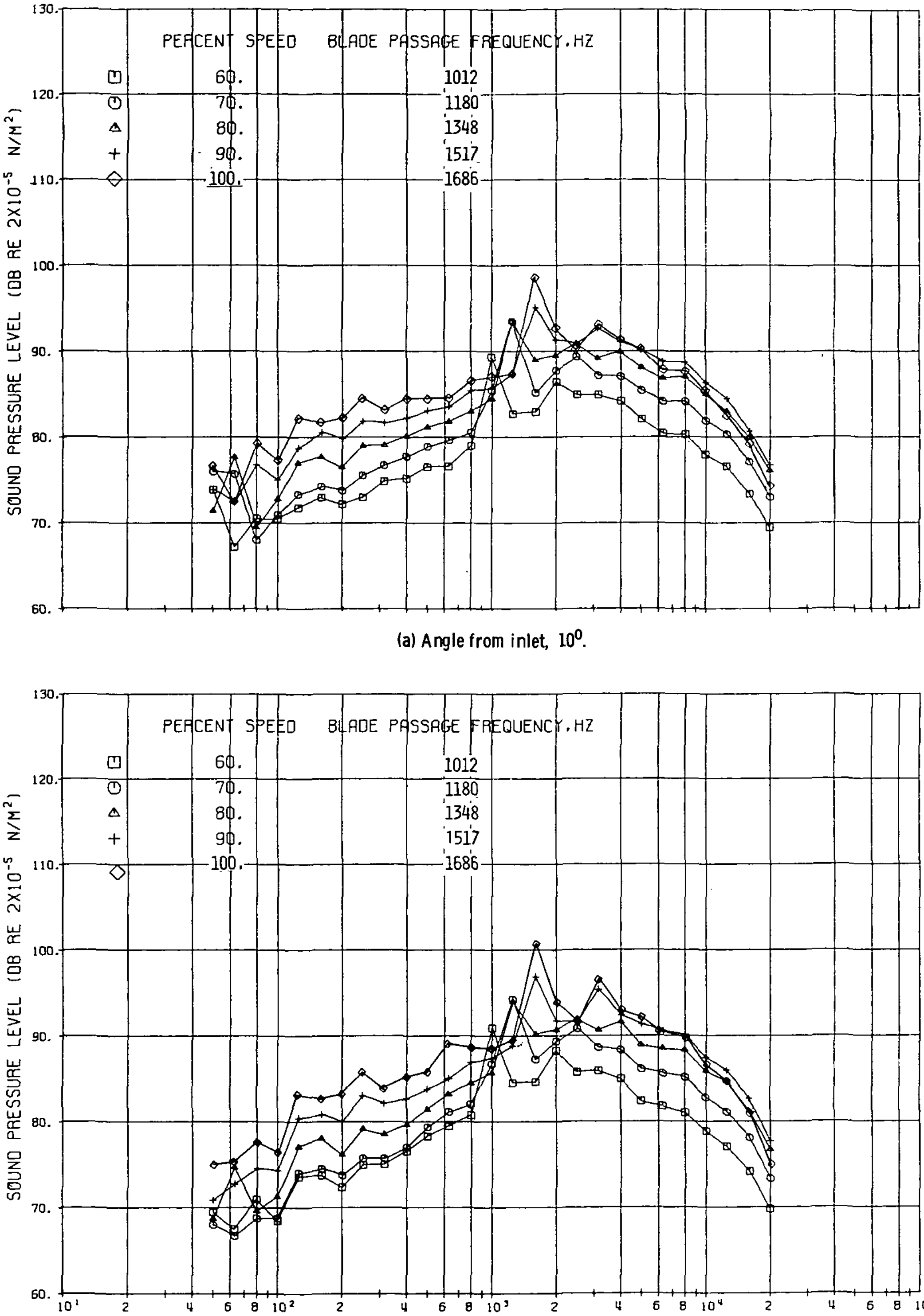
(b) QF-9 at 60, 70, 86, and 93 percent of design speed.

Figure 23. - Perceived noise on 30.5-meter radius.



(c) QF-9 at 100, 110, 115, and 120 percent of design speed.

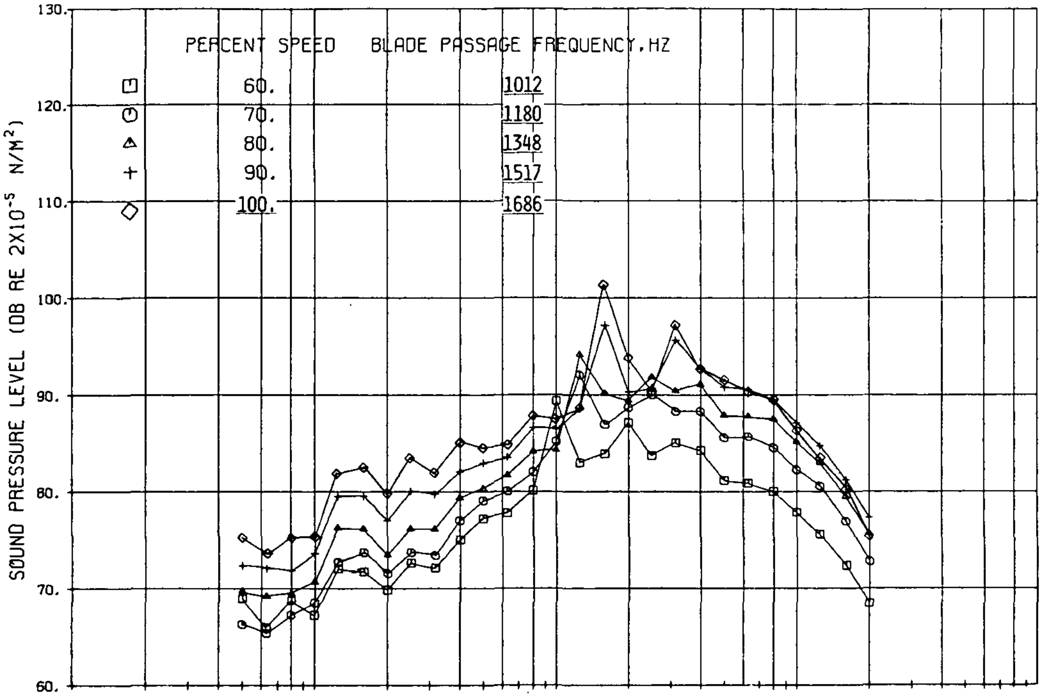
Figure 23. - Concluded.



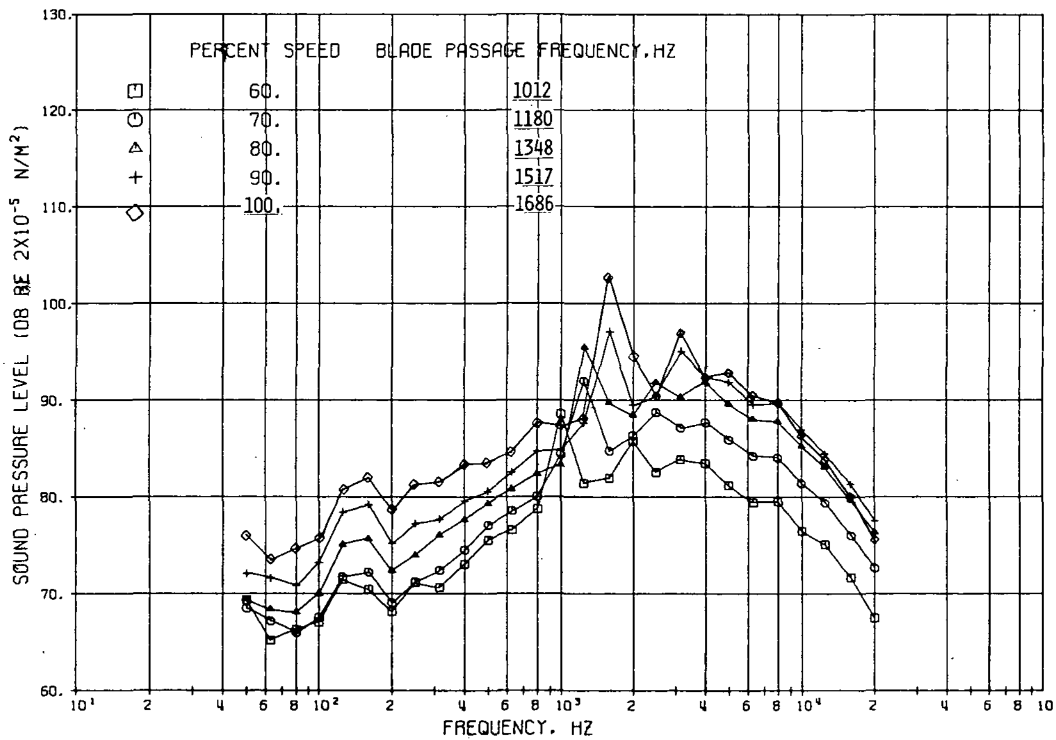
(a) Angle from inlet, 10^{0}.

(b) Angle from inlet, 20^{0}.

Figure 24. - One-third-octave-band spectra on 30.5-meter radius for QF-6 at 60, 70, 80, 90, and 100 percent of design speed, for various angles from the inlet.

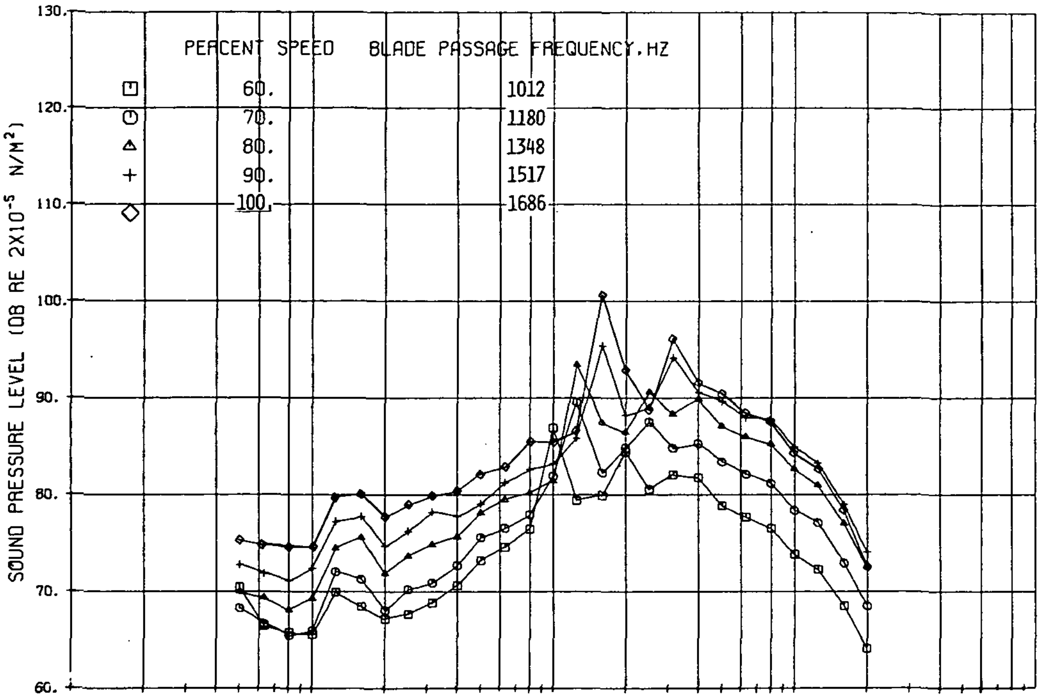


(c) Angle from inlet, 30°.

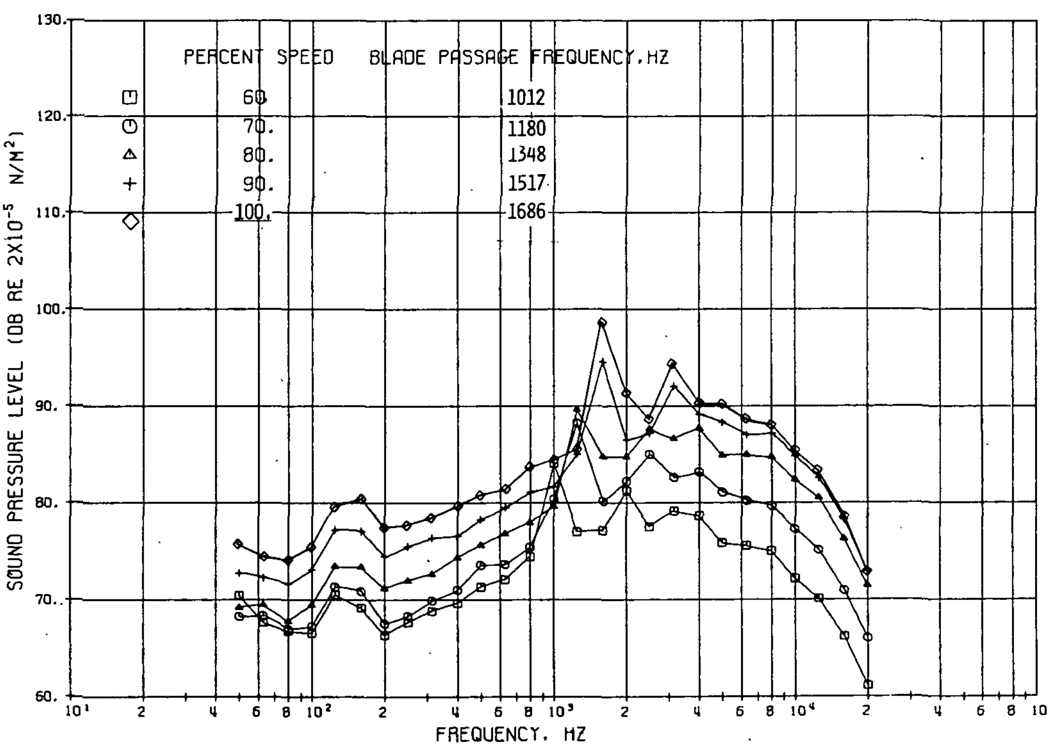


(d) Angle from inlet, 40°.

Figure 24. - Continued.

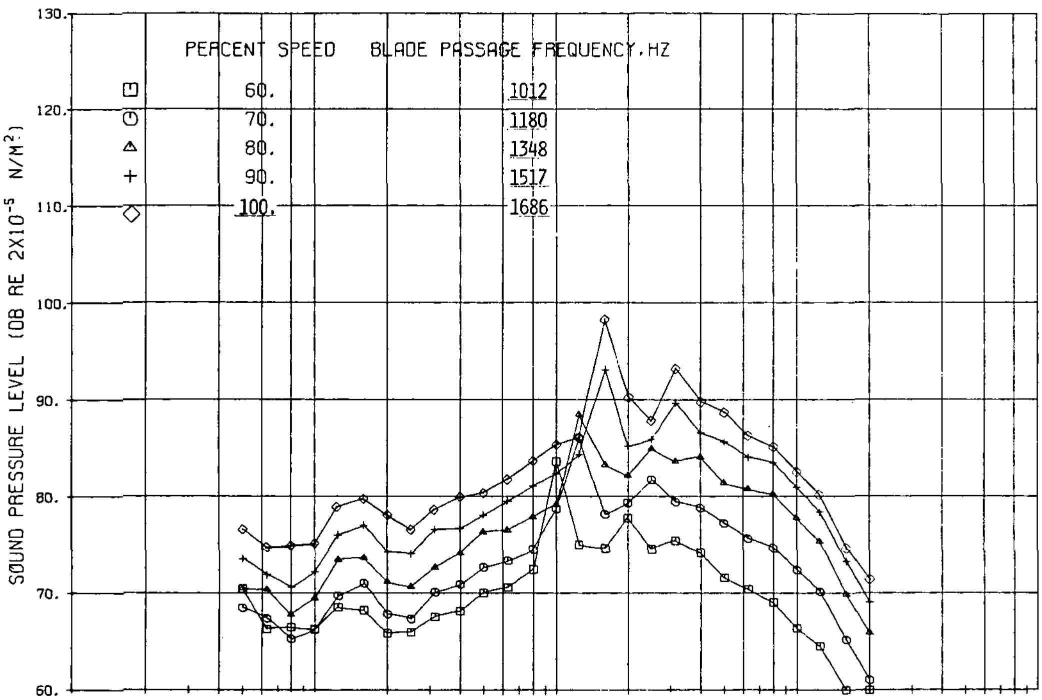


(e) Angle from inlet, 50^0.

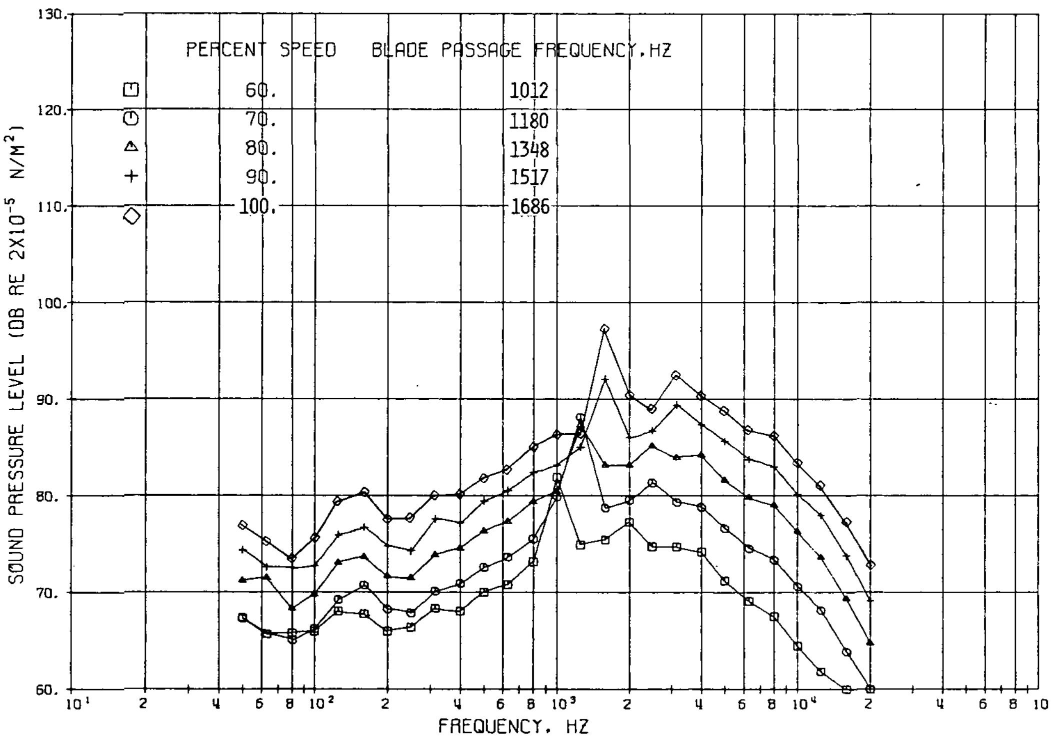


(f) Angle from inlet, 60^0.

Figure 24. - Continued.

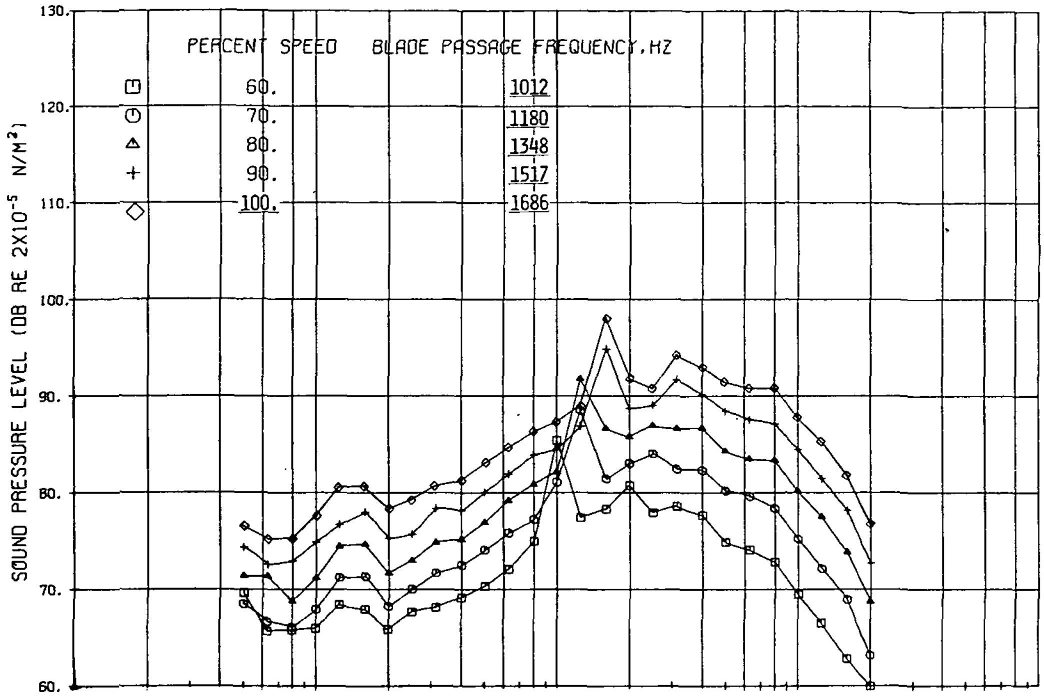


(g) Angle from inlet, 70°.

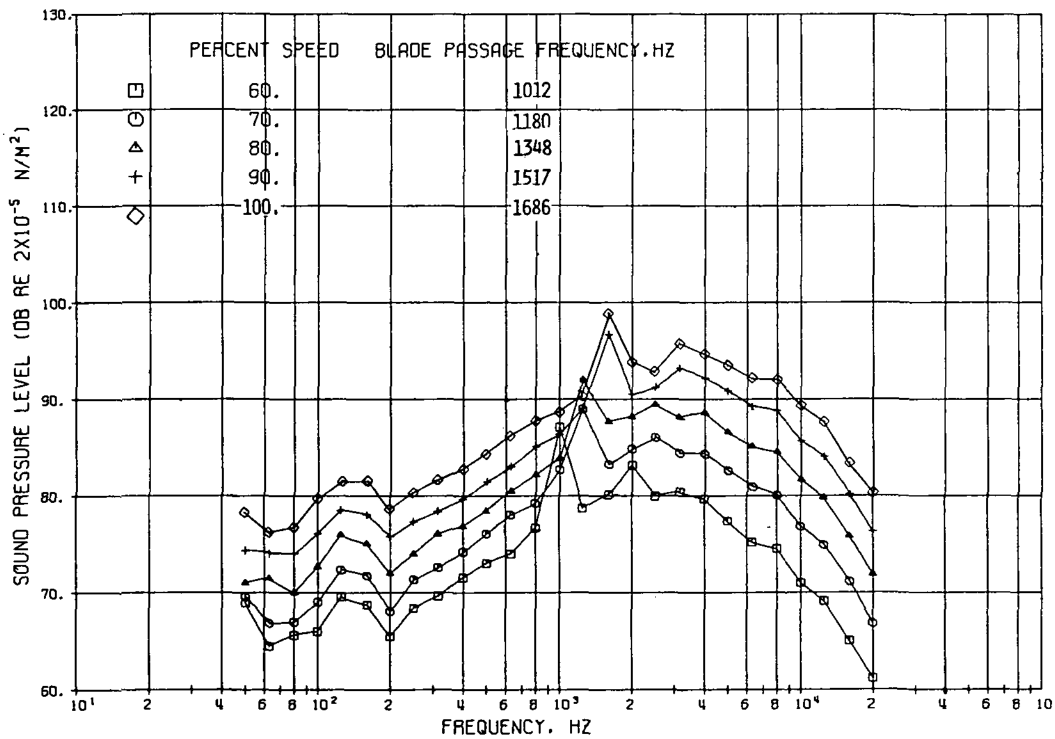


(h) Angle from inlet, 80°.

Figure 24. - Continued.

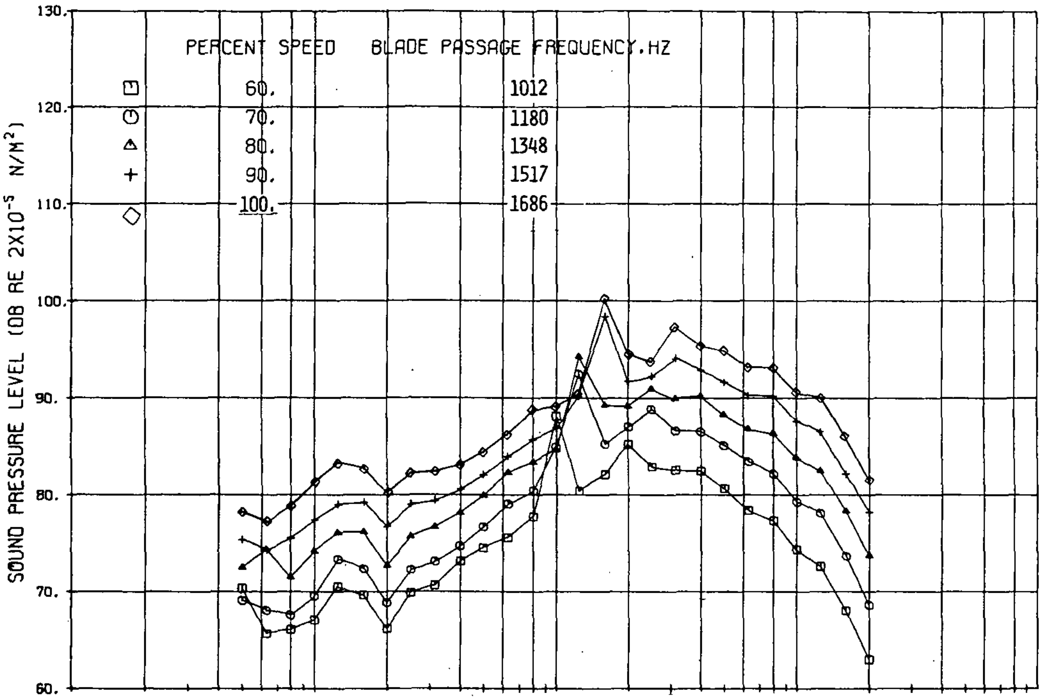


(i) Angle from inlet, 90°.

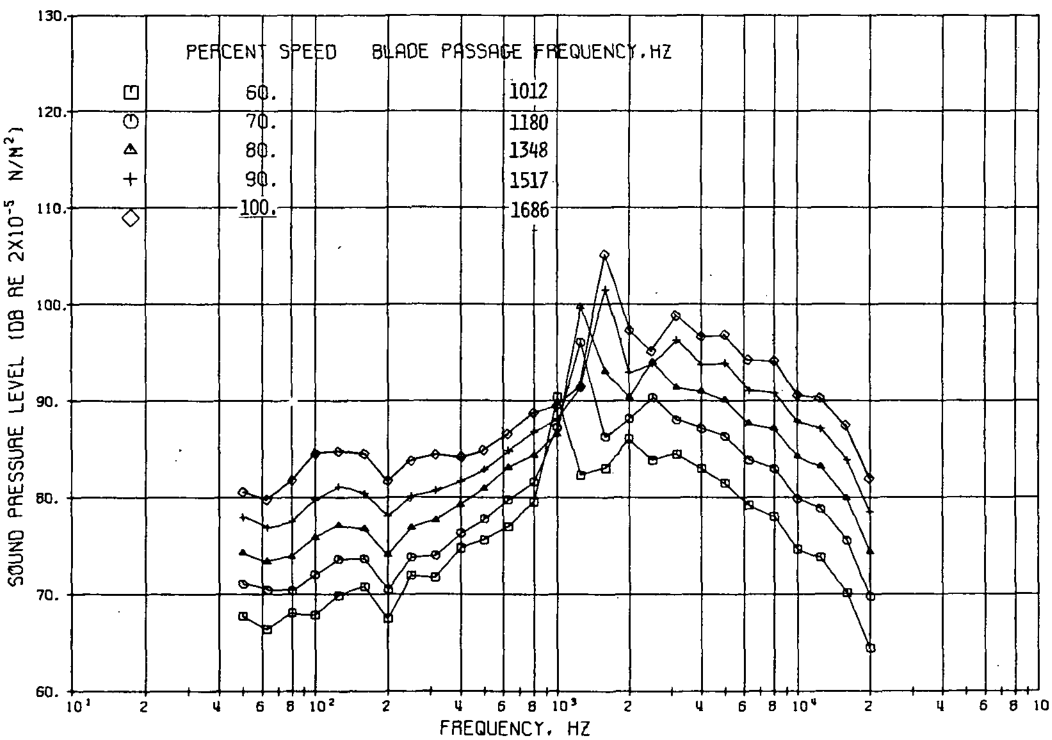


(j) Angle from inlet, 100°.

Figure 24. - Continued.

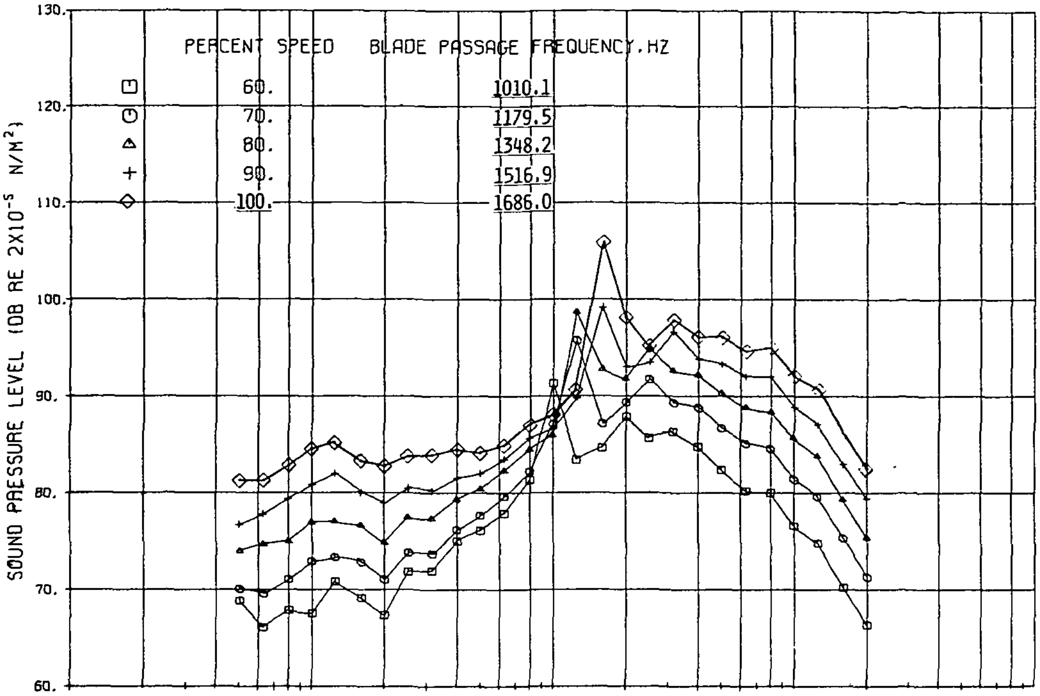


(k) Angle from inlet, 110°.

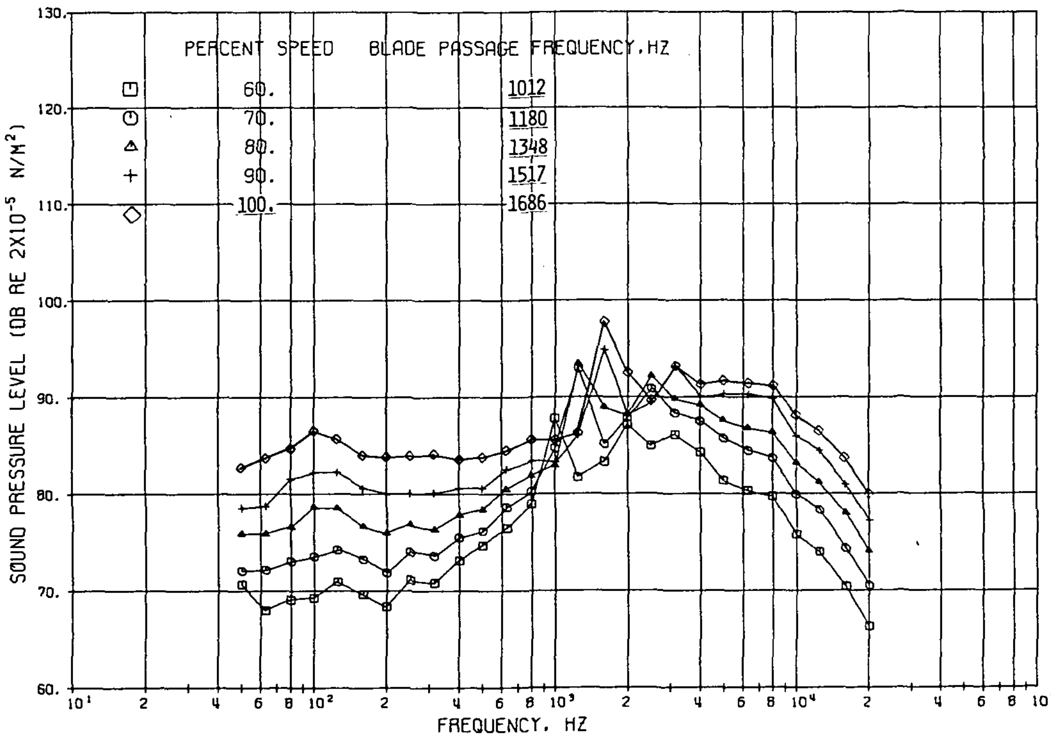


(ℓ) Angle from inlet, 120°.

Figure 24. - Continued.

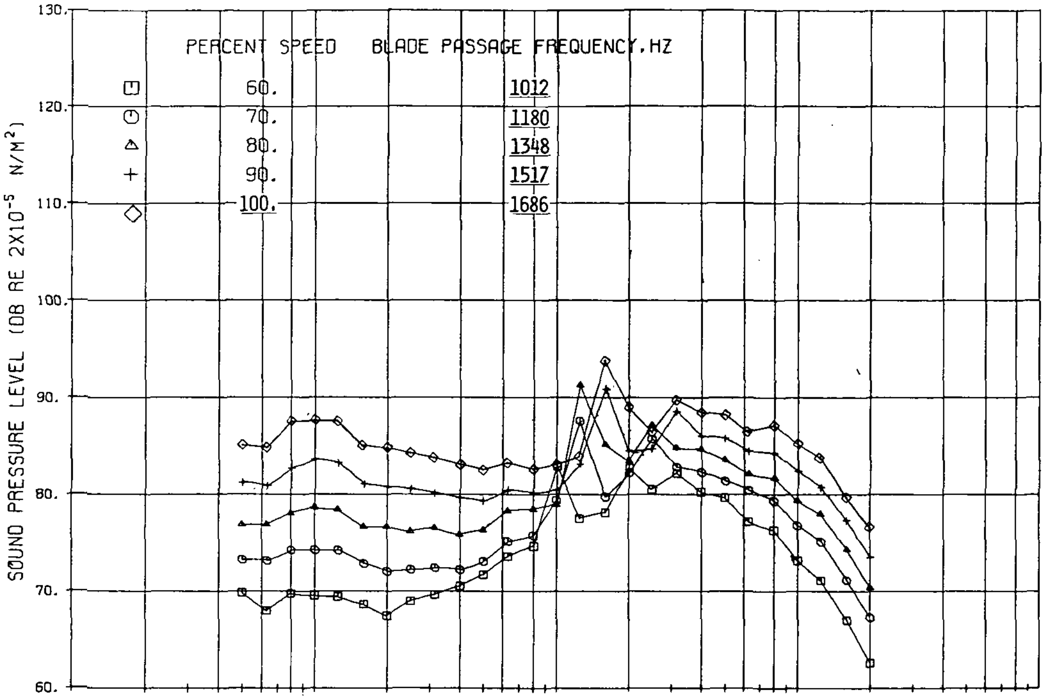


(m) Angle from inlet, 130°.

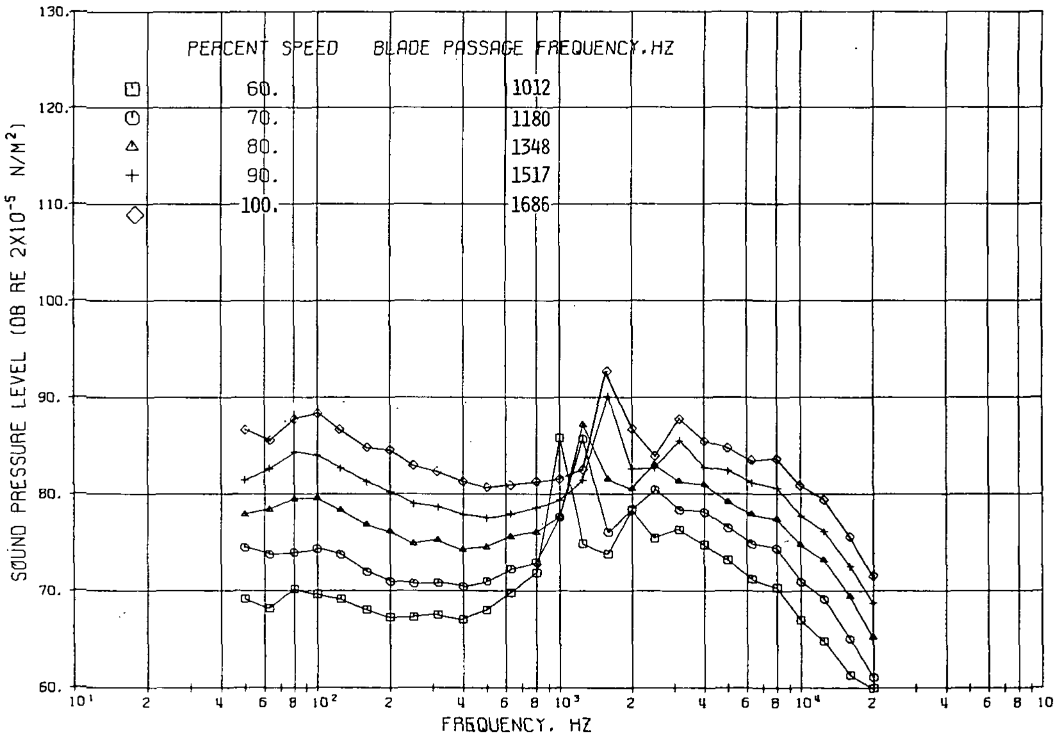


(n) Angle from inlet, 140°.

Figure 24. - Continued.

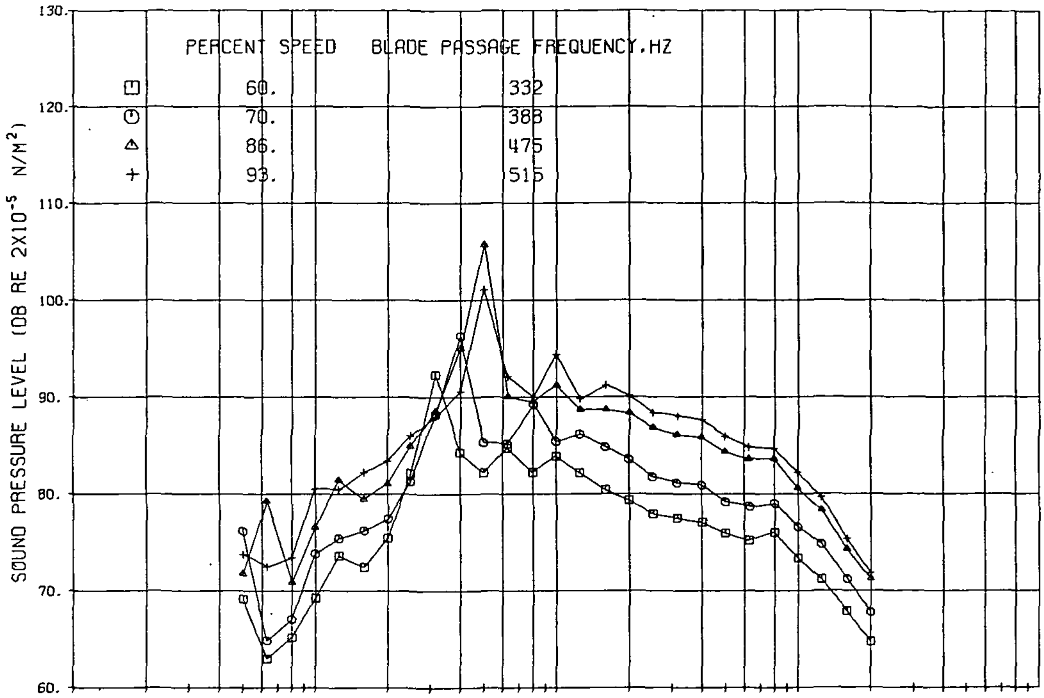


(o) Angle from inlet, 150°.

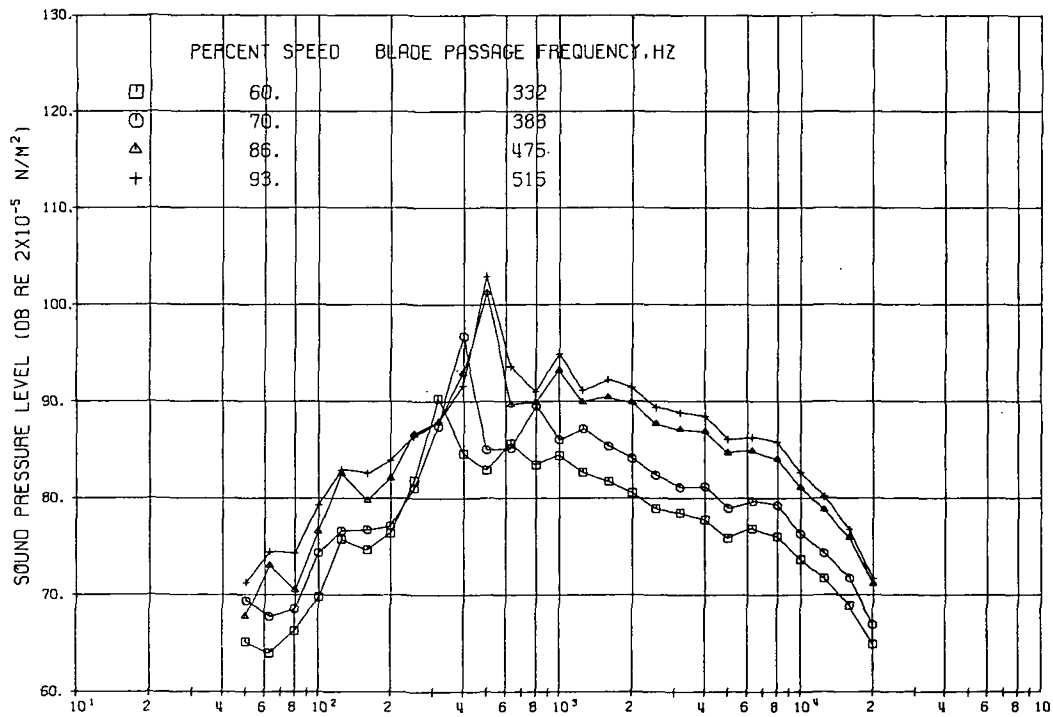


(p) Angle from inlet, 160°.

Figure 24. - Concluded.

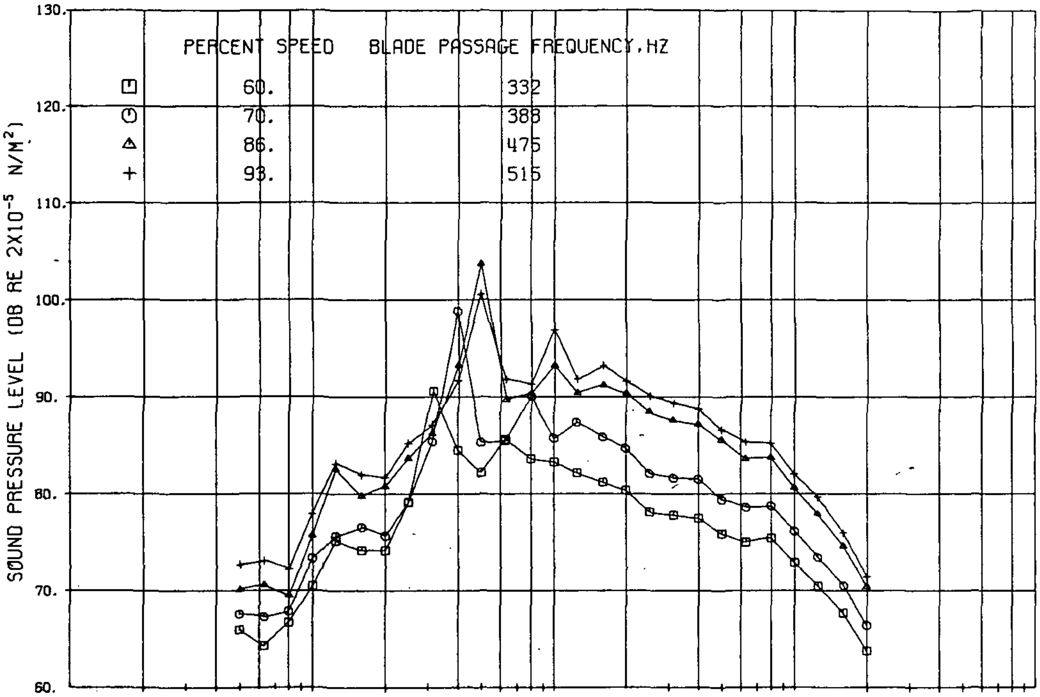


(a) Angle from inlet, 10°.

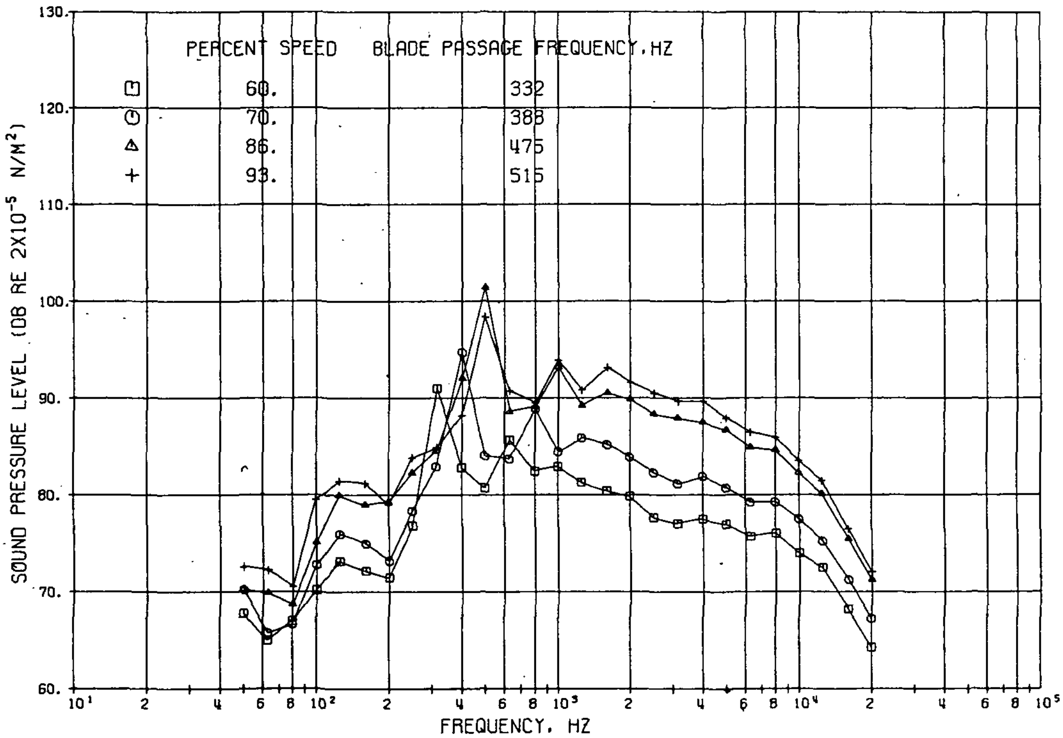


(b) Angle from inlet, 20°.

Figure 25. - One-third-octave-band spectra on 30.5-meter radius for QF-9 at 60, 70, 86, and 93 percent of design speed, for various angles from the inlet.

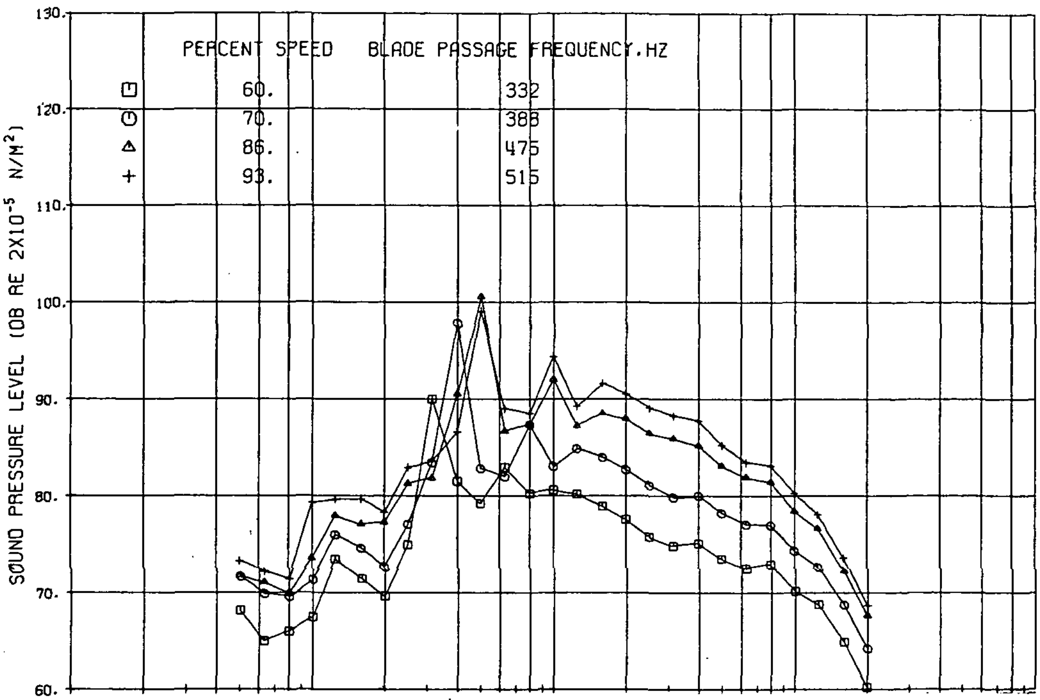


(c) Angle from inlet, 30°.

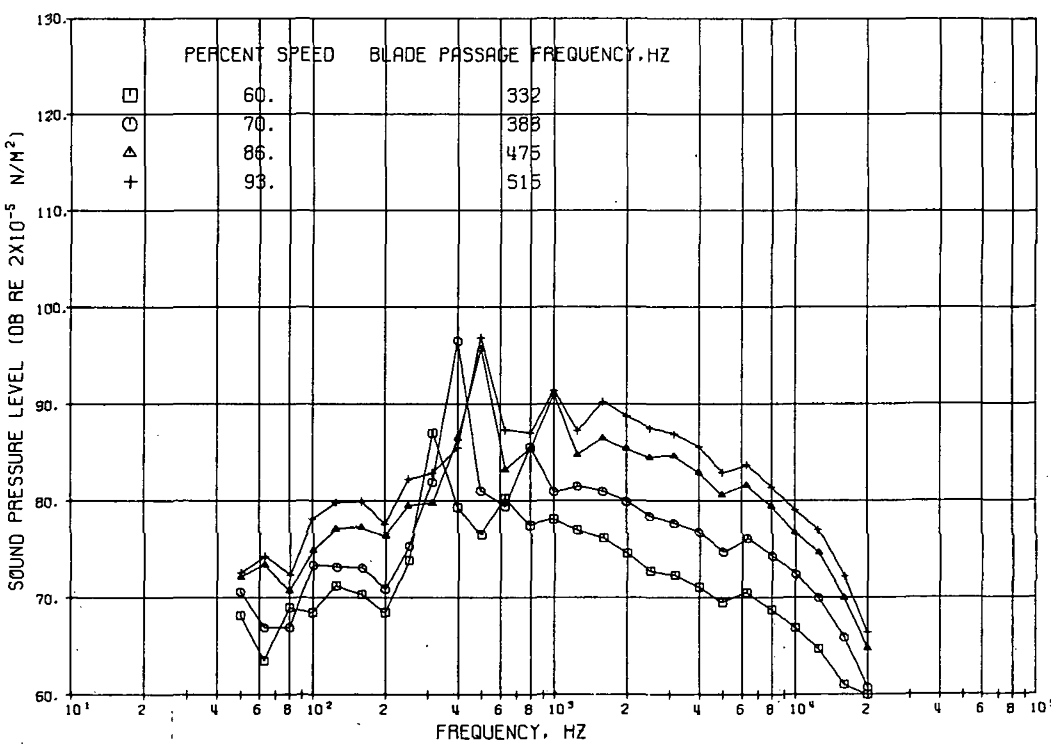


(d) Angle from inlet, 40°.

Figure 25. - Continued.

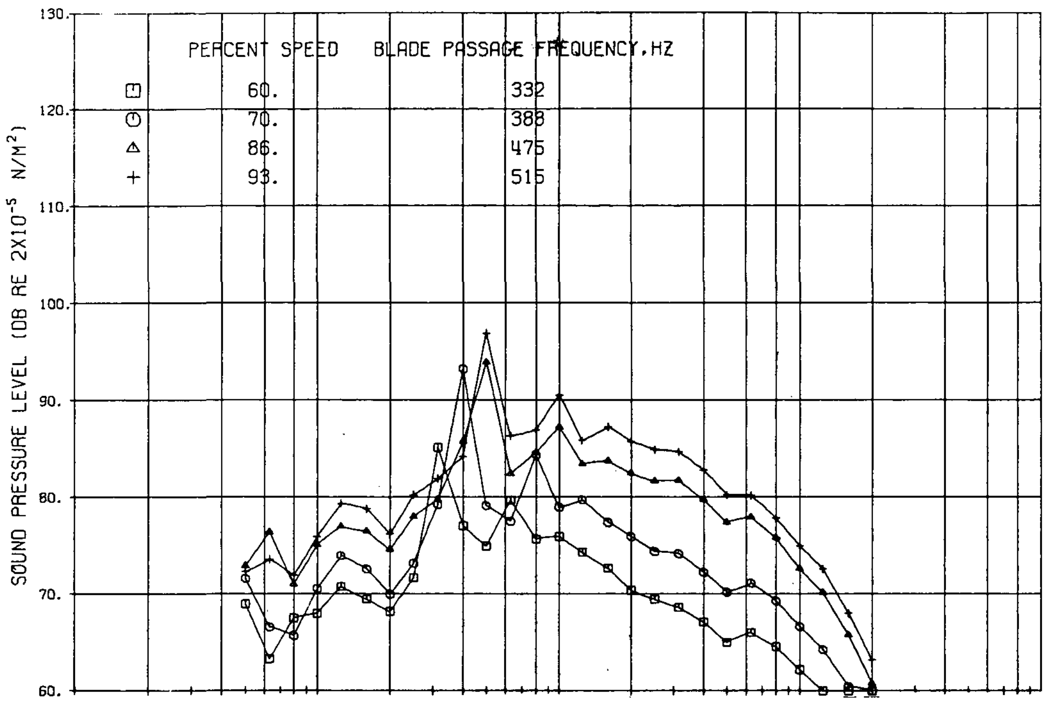


(e) Angle from inlet, 50°.

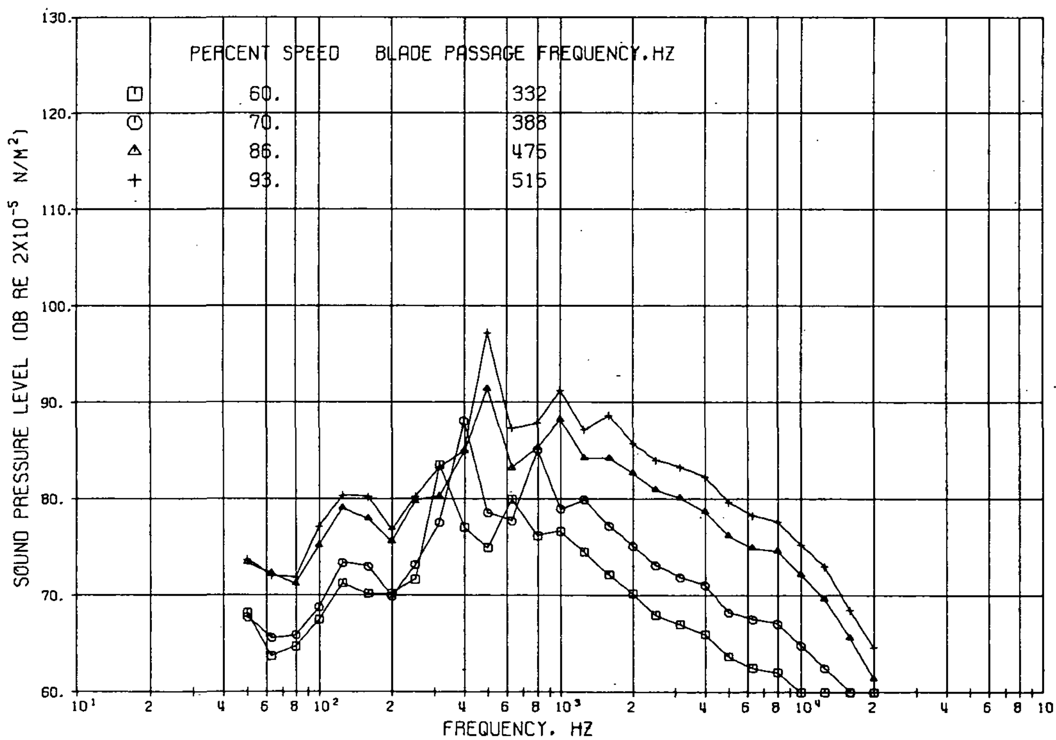


(f) Angle from inlet, 60°.

Figure 25. - Continued.

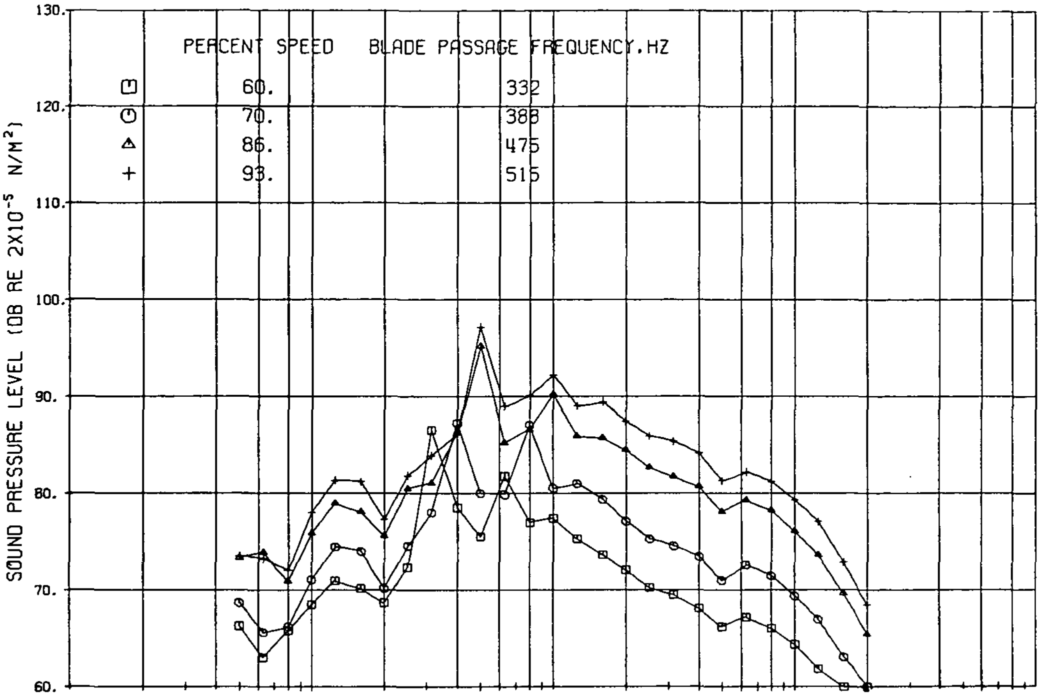


(g) Angle from inlet, 70°.

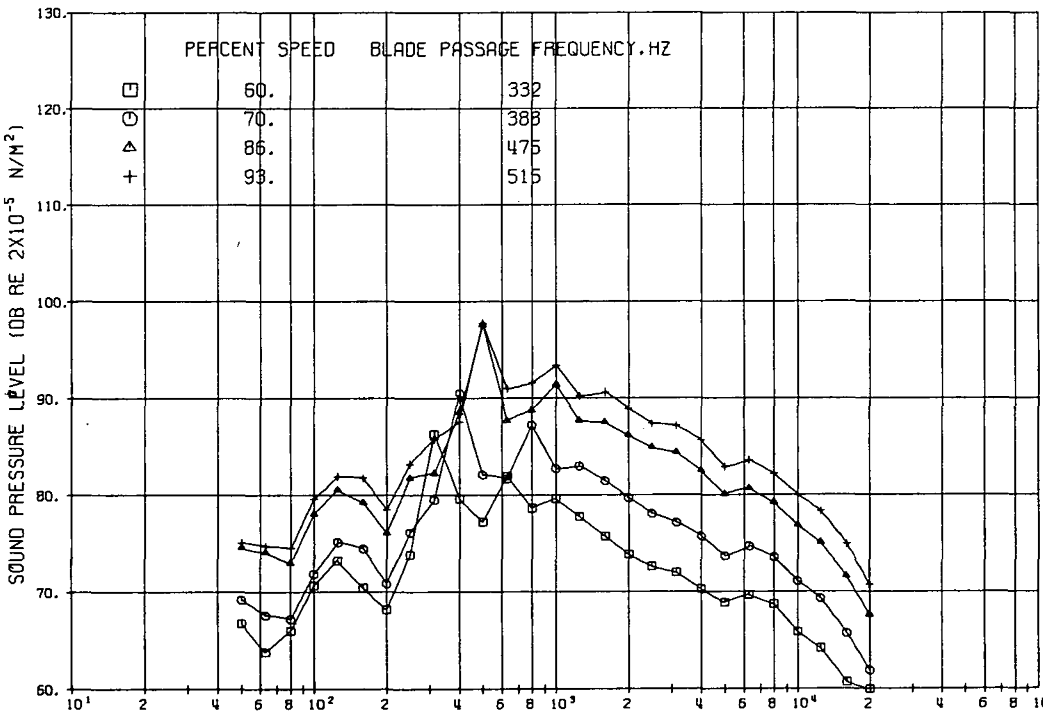


(h) Angle from inlet, 80°.

Figure 25. - Continued.

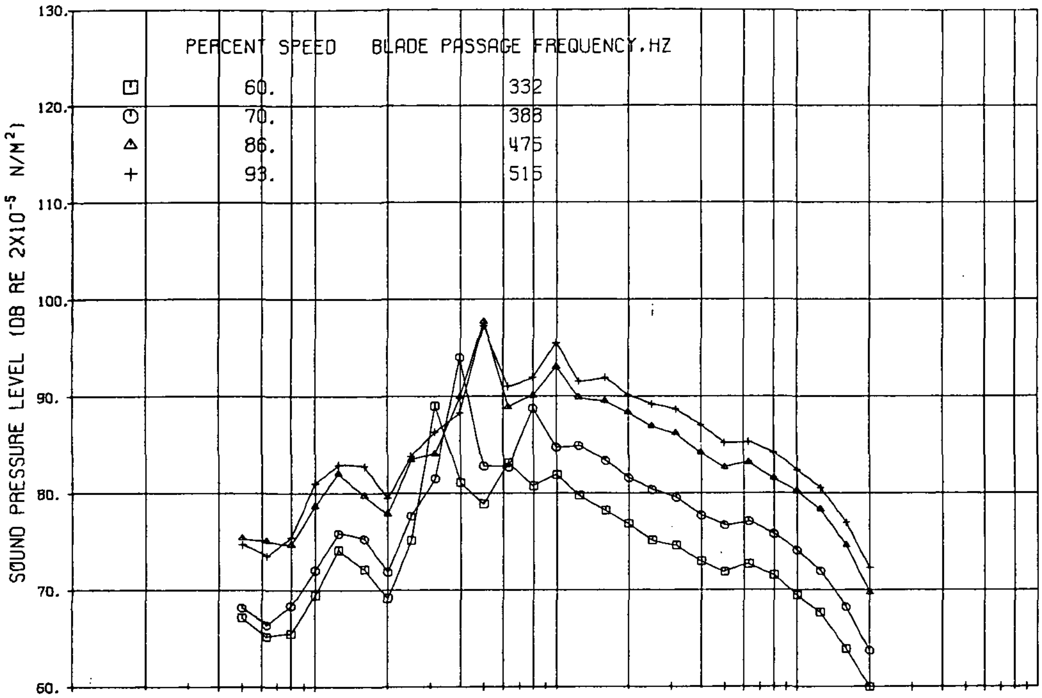


(i) Angle from inlet, 90°.

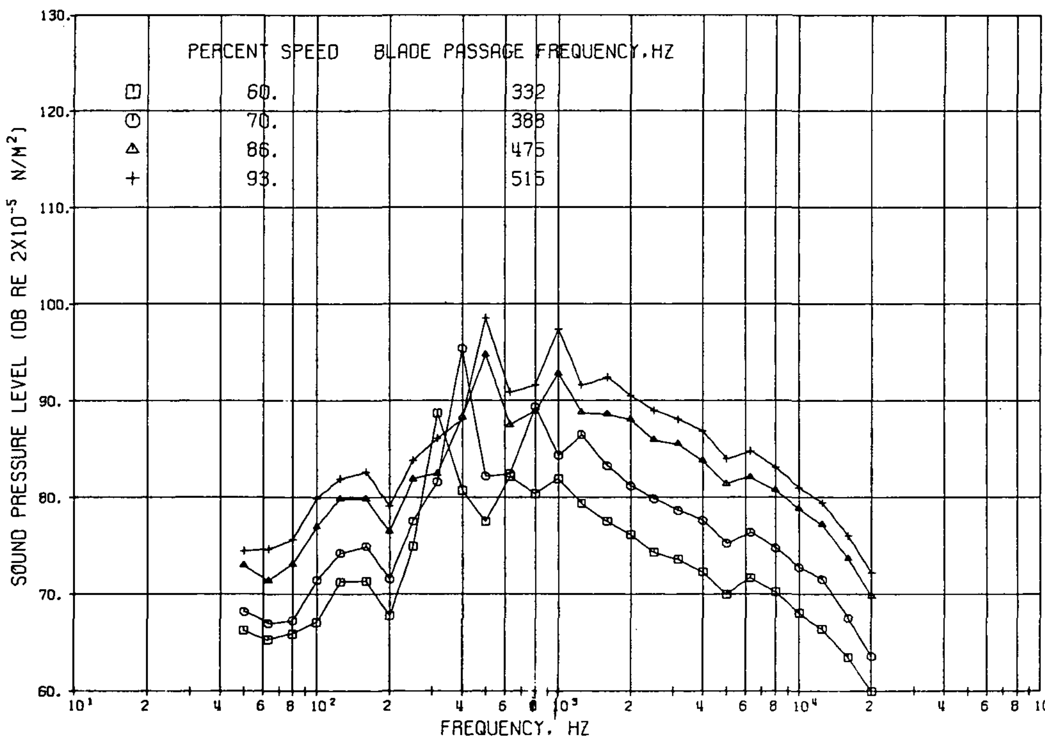


(j) Angle from inlet, 100°.

Figure 25. - Continued.

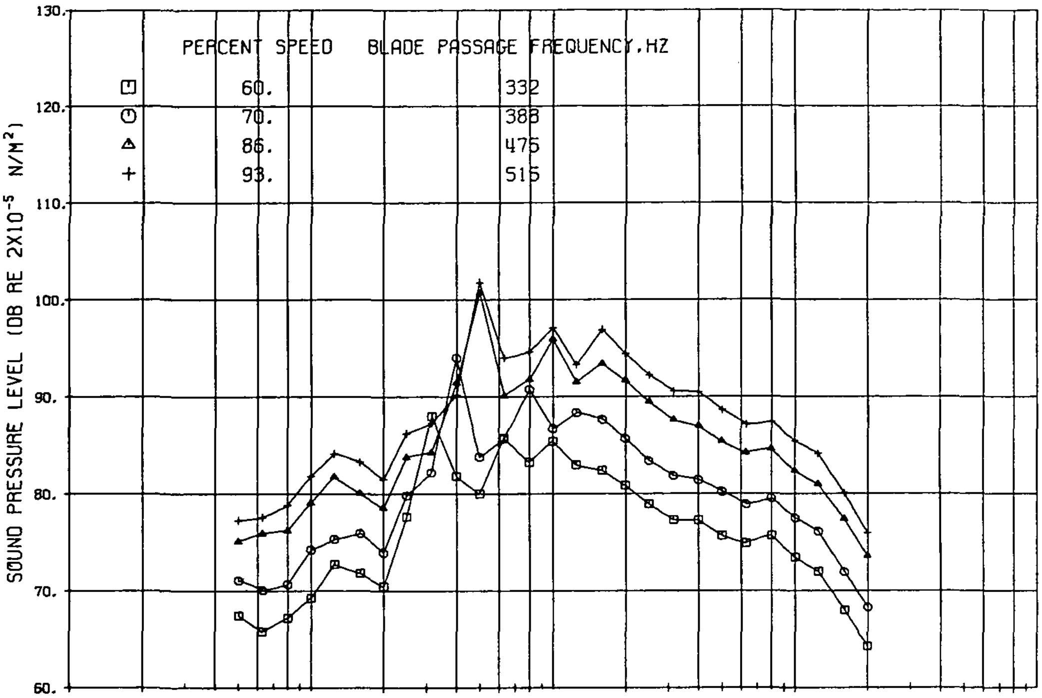


(k) Angle from inlet, 110°.

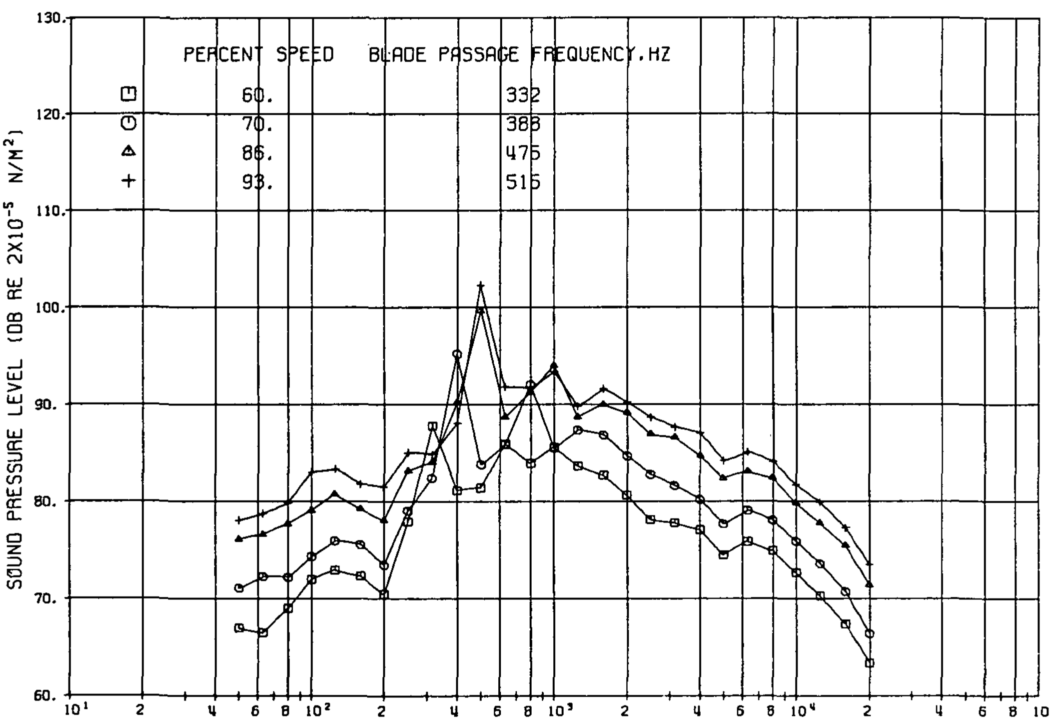


(ℓ) Angle from inlet, 120°.

Figure 25. - Continued.

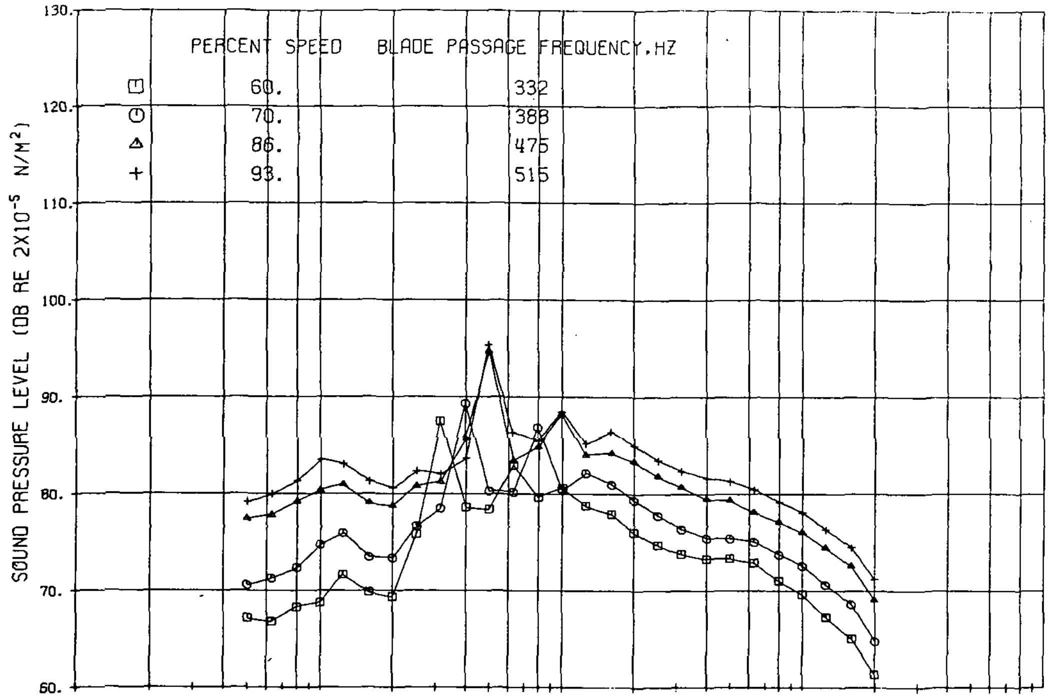


(m) Angle from inlet, 130°.

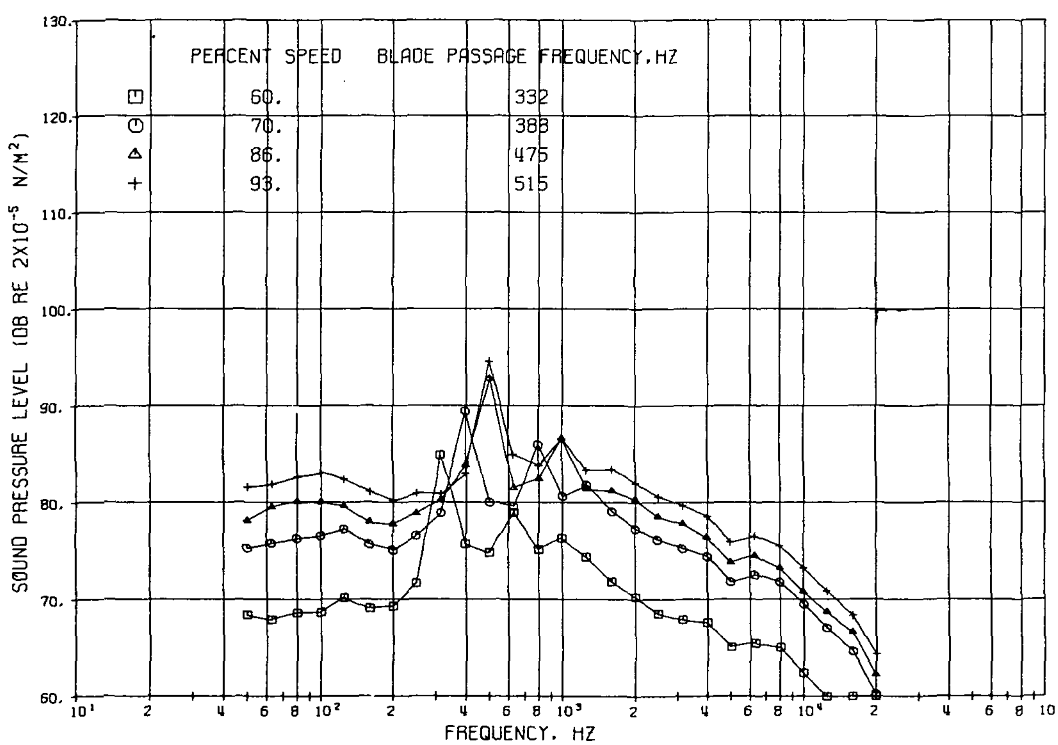


(n) Angle from inlet, 140°.

Figure 25. - Continued.

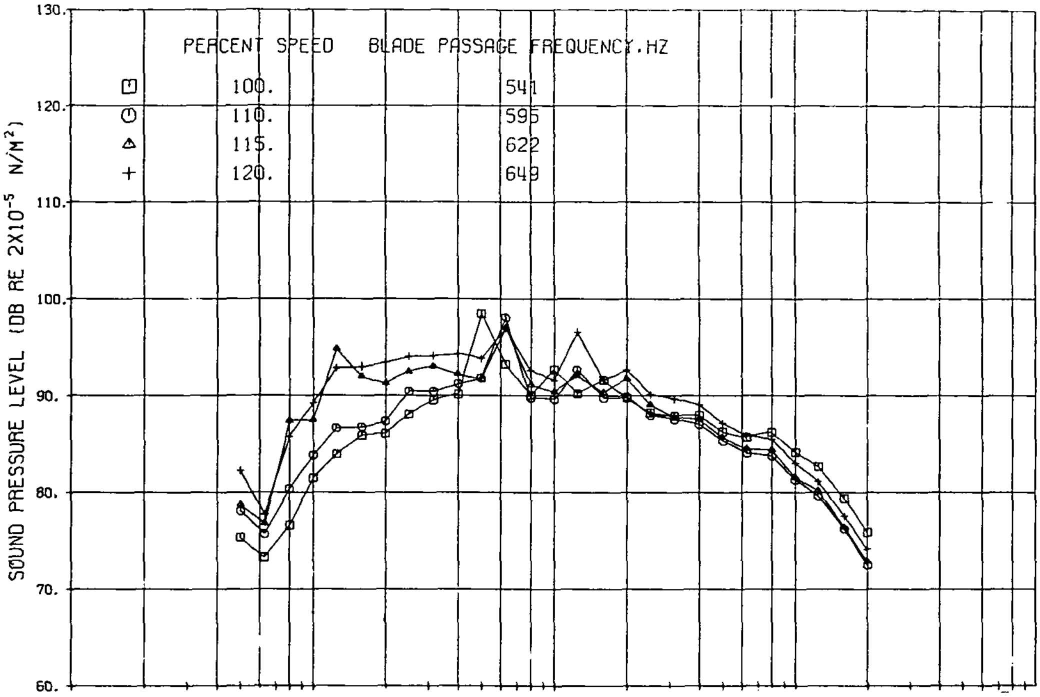


(o) Angle from inlet, 150°.

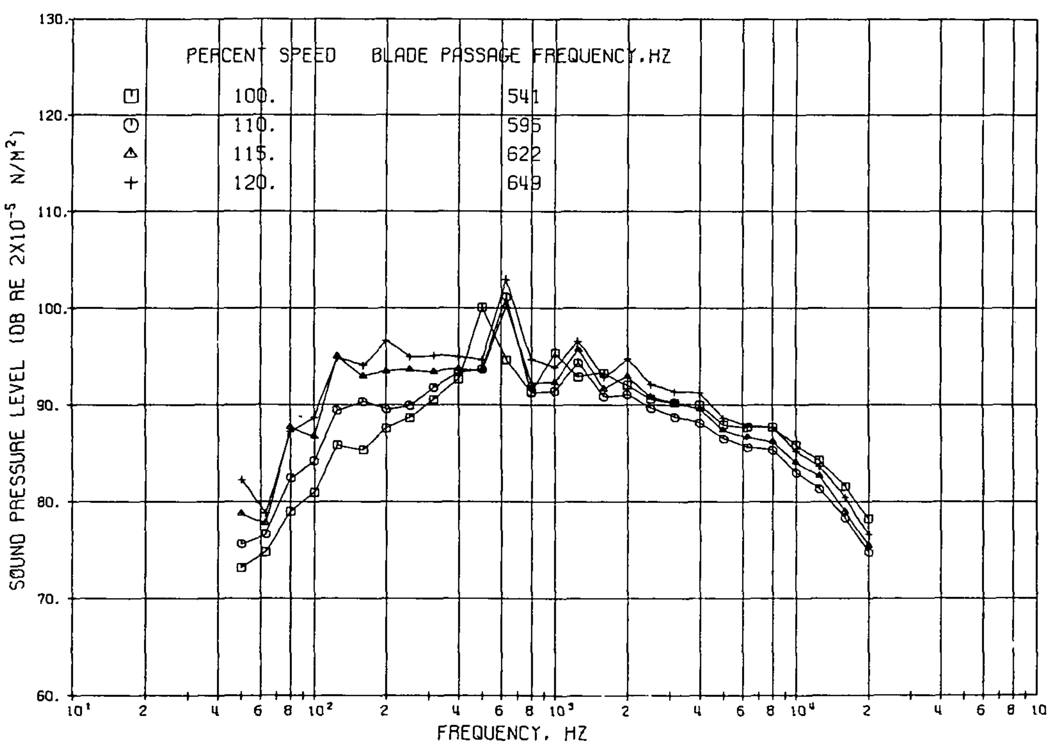


(p) Angle from inlet, 160°.

Figure 25. - Concluded.

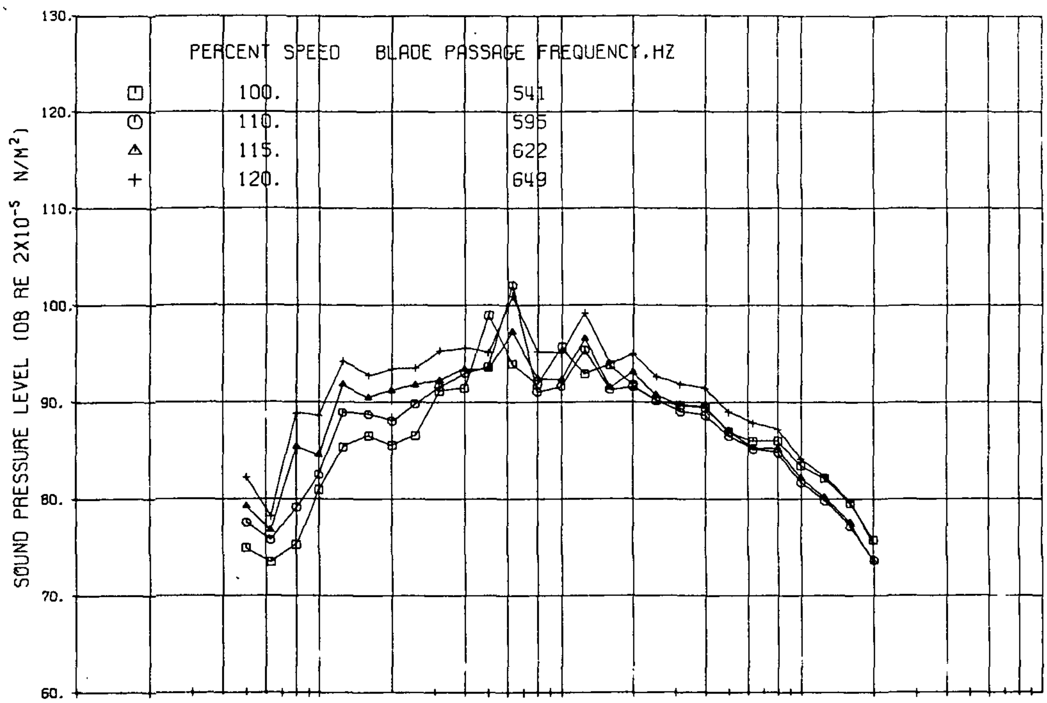


(a) Angle from inlet, 10^0.

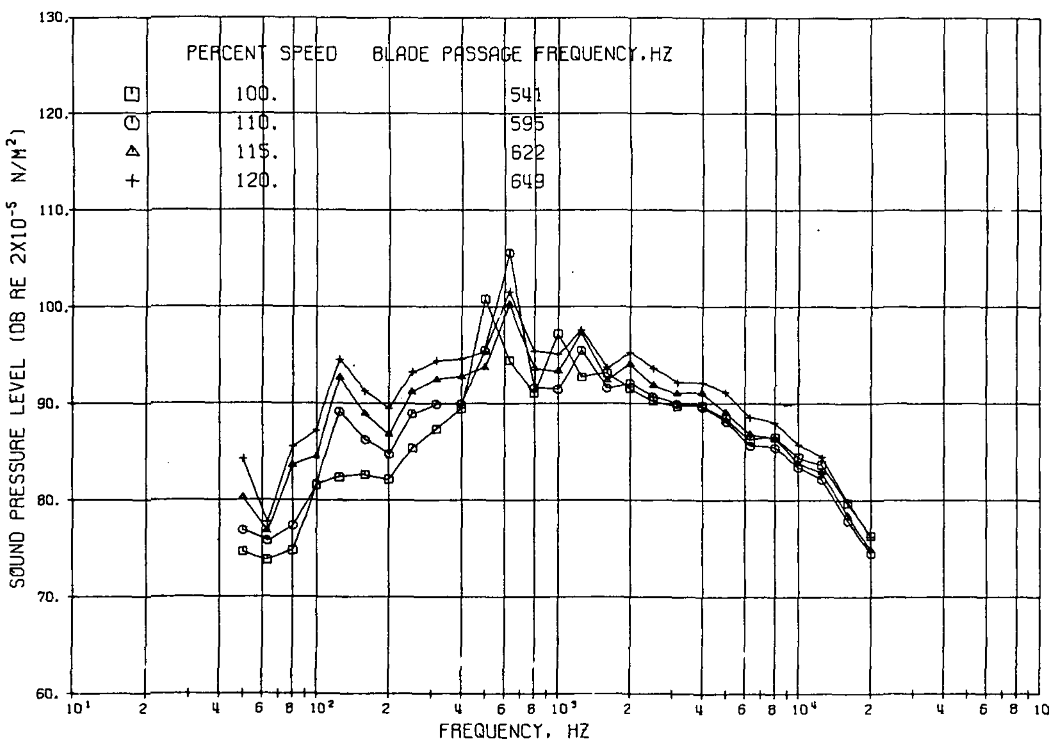


(b) Angle from inlet, 20^0.

Figure 26. - One-third-octave-band spectra on 30.5-meter radius for QF-9 at 100, 110, 115, and 120 percent of design speed, for various angles from the inlet.

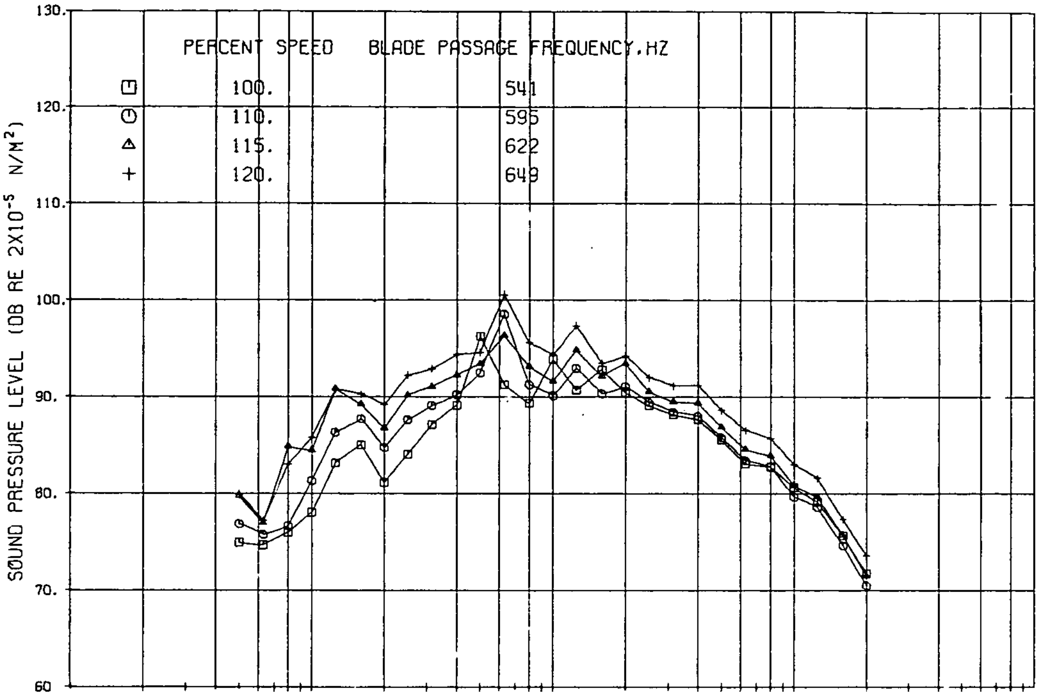


(c) Angle from inlet, 30°.

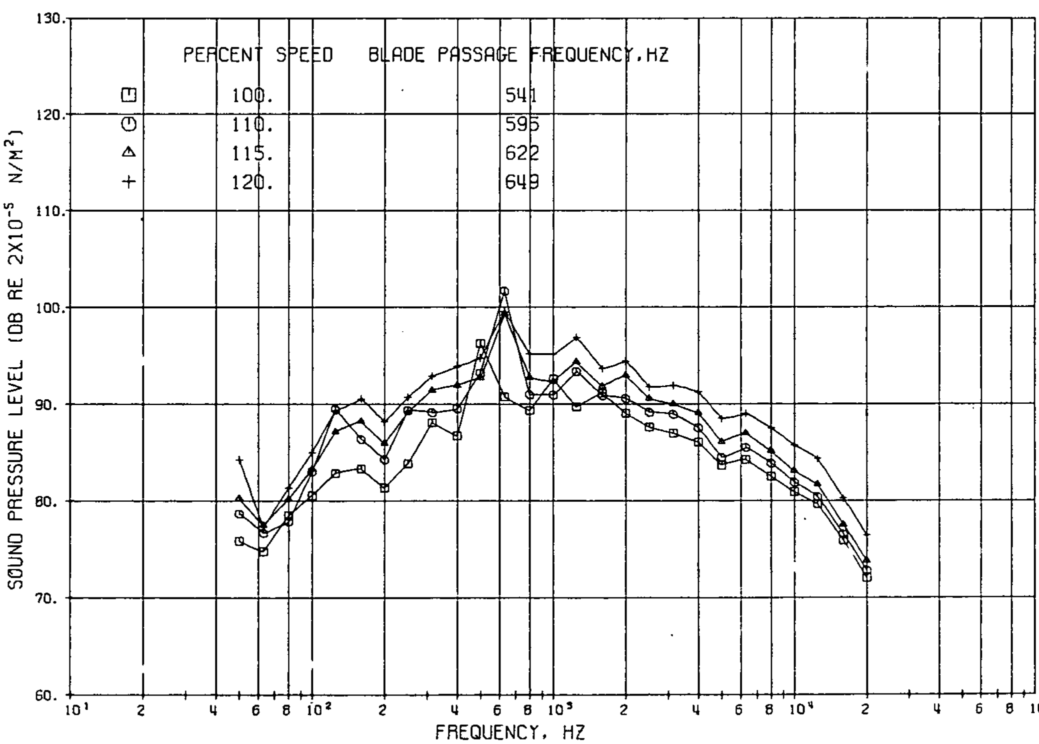


(d) Angle from inlet, 40°.

Figure 26. - Continued.

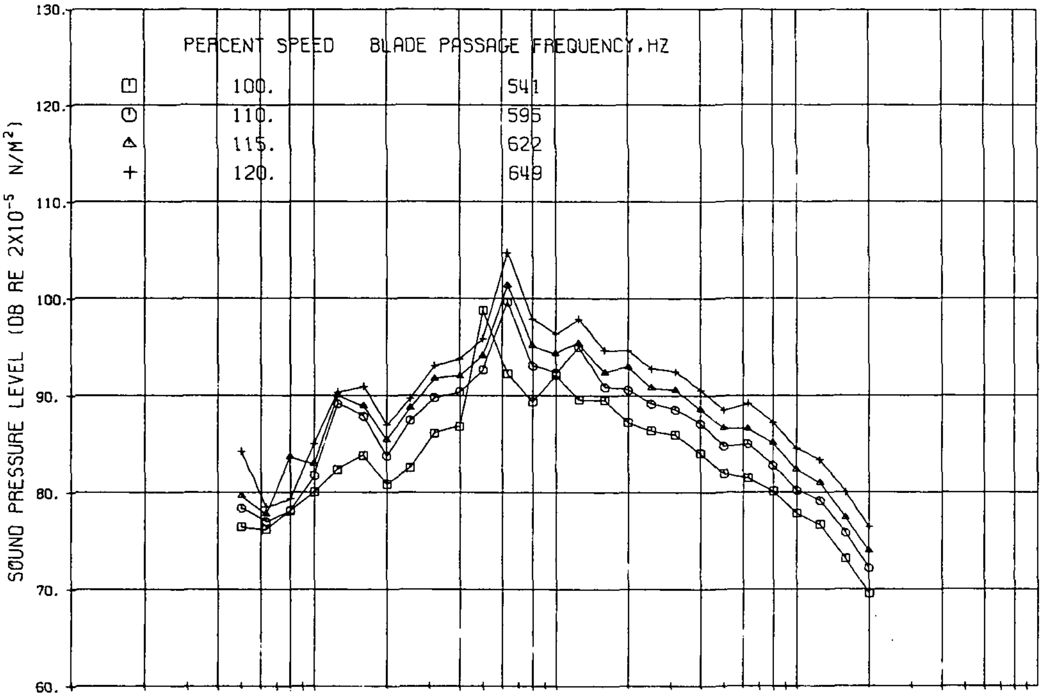


(e) Angle from inlet, 50°.

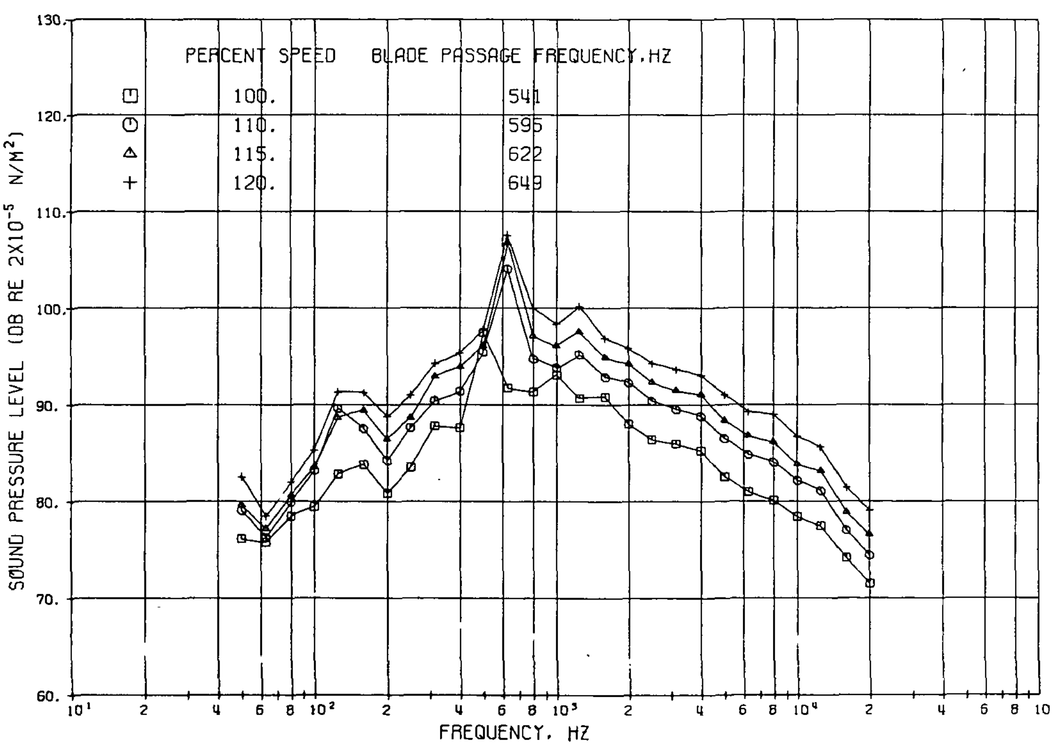


(f) Angle from inlet, 60°.

Figure 26. - Continued.

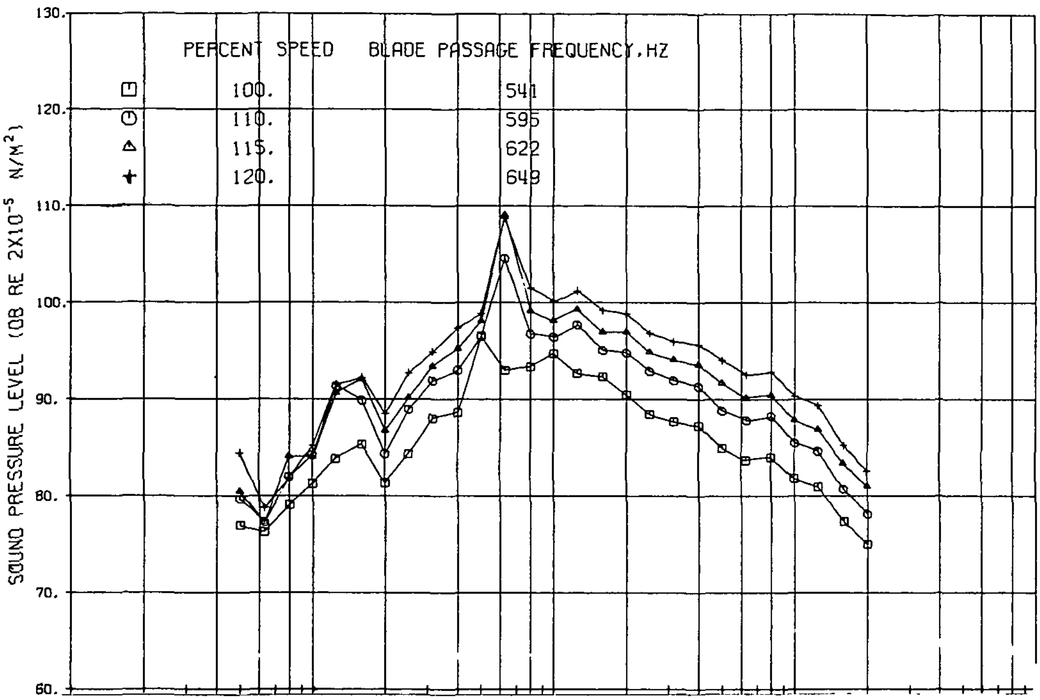


(g) Angle from inlet, 70°.

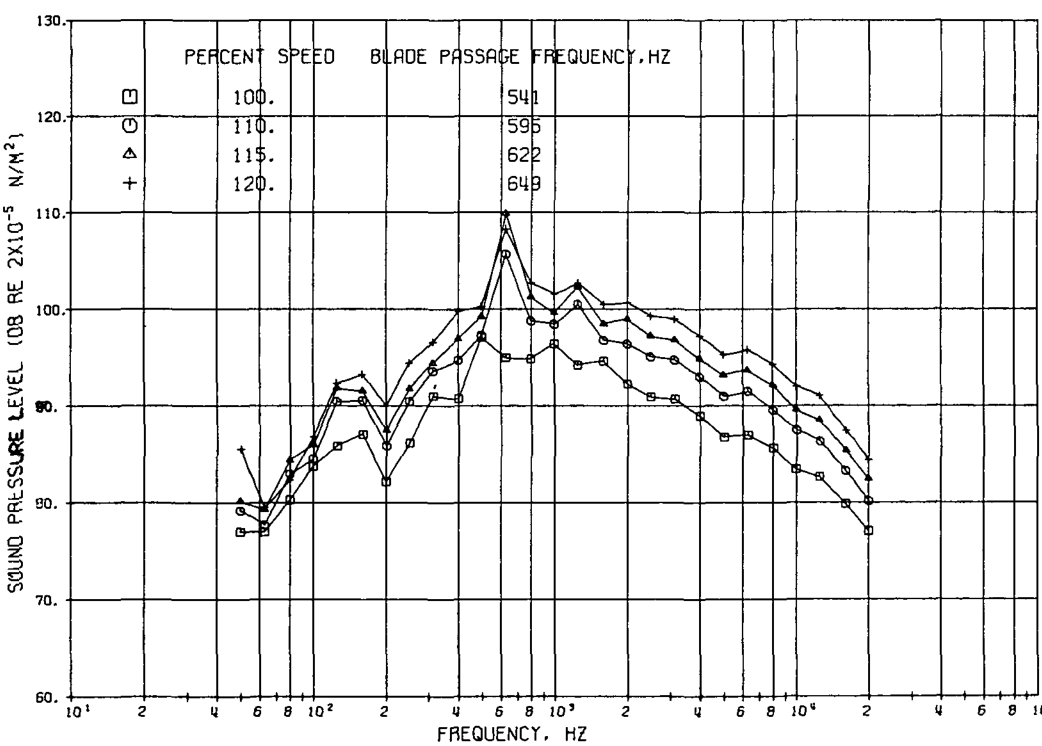


(h) Angle from inlet, 80°.

Figure 26. - Continued.

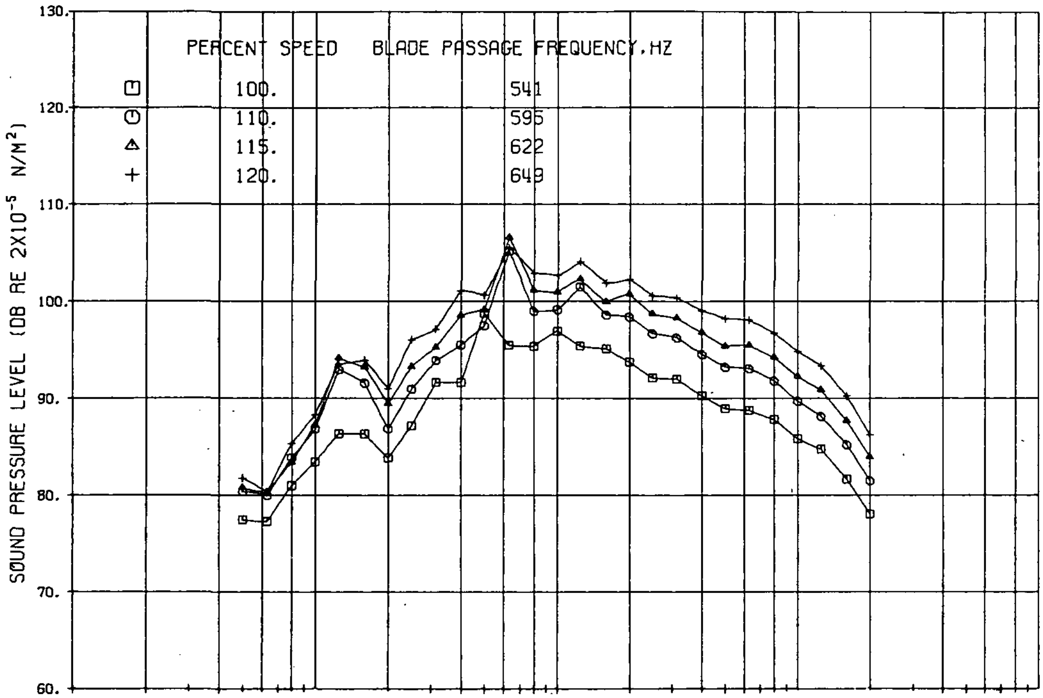


(i) Angle from inlet, 90°.

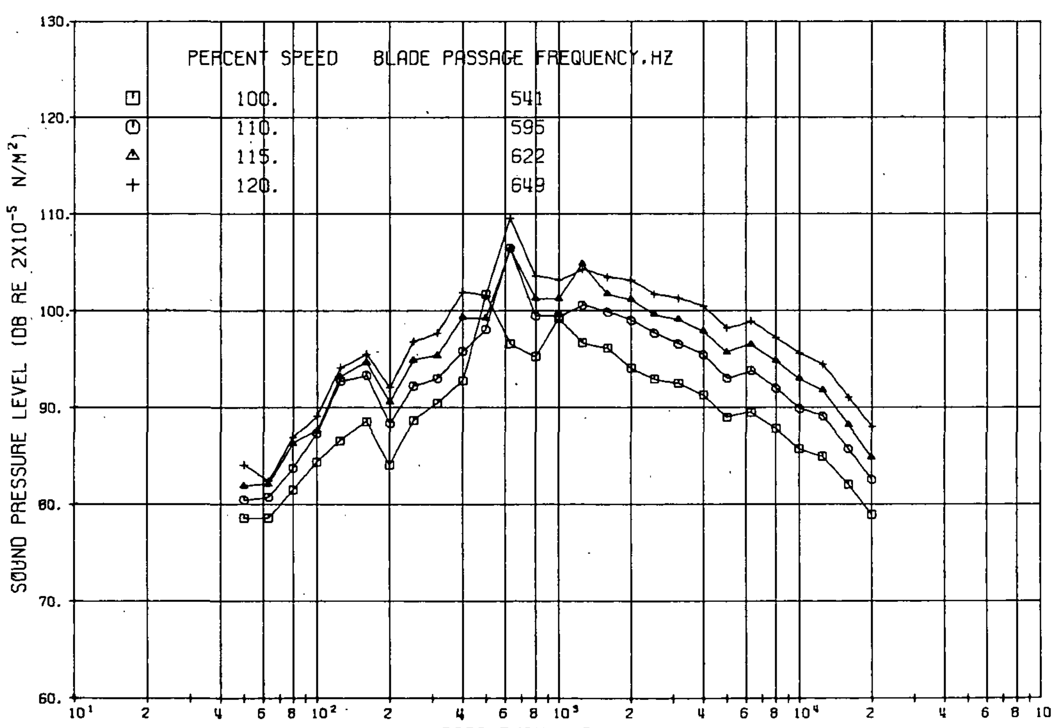


(j) Angle from inlet, 100°.

Figure 26. - Continued.

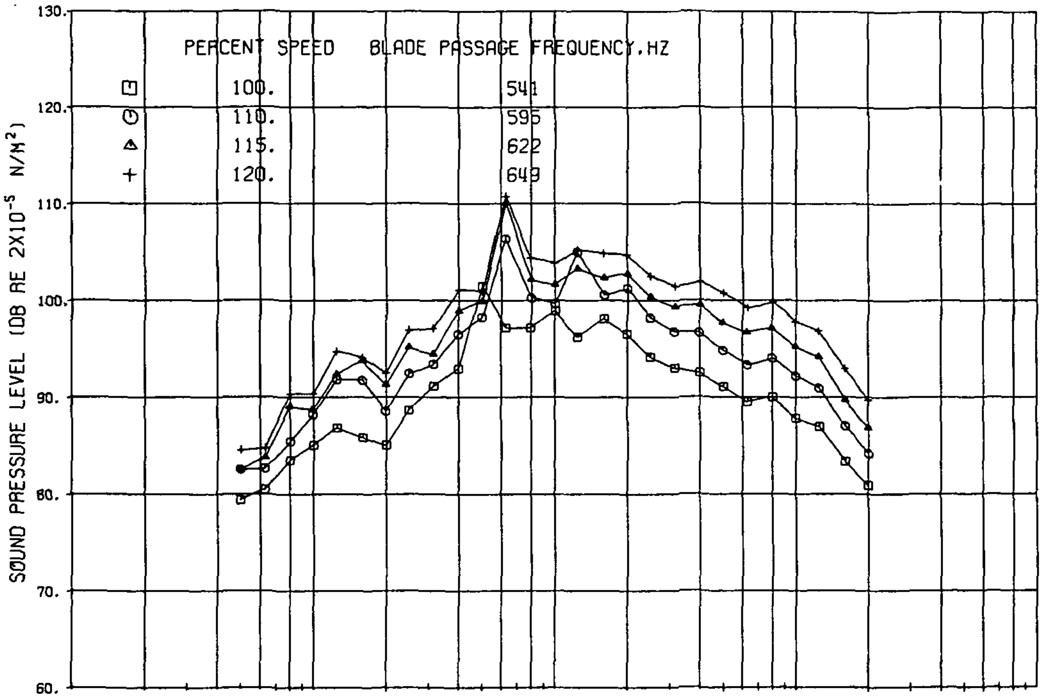


(k) Angle from inlet, 110°.

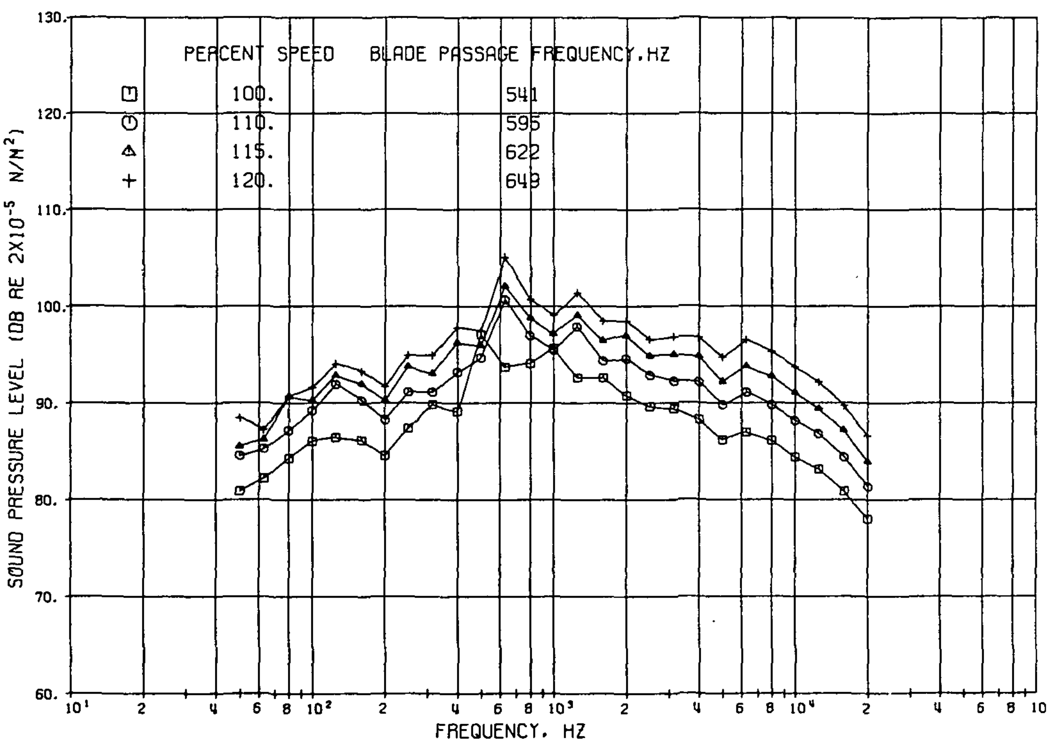


(ℓ) Angle from inlet, 120°.

Figure 26. - Continued.

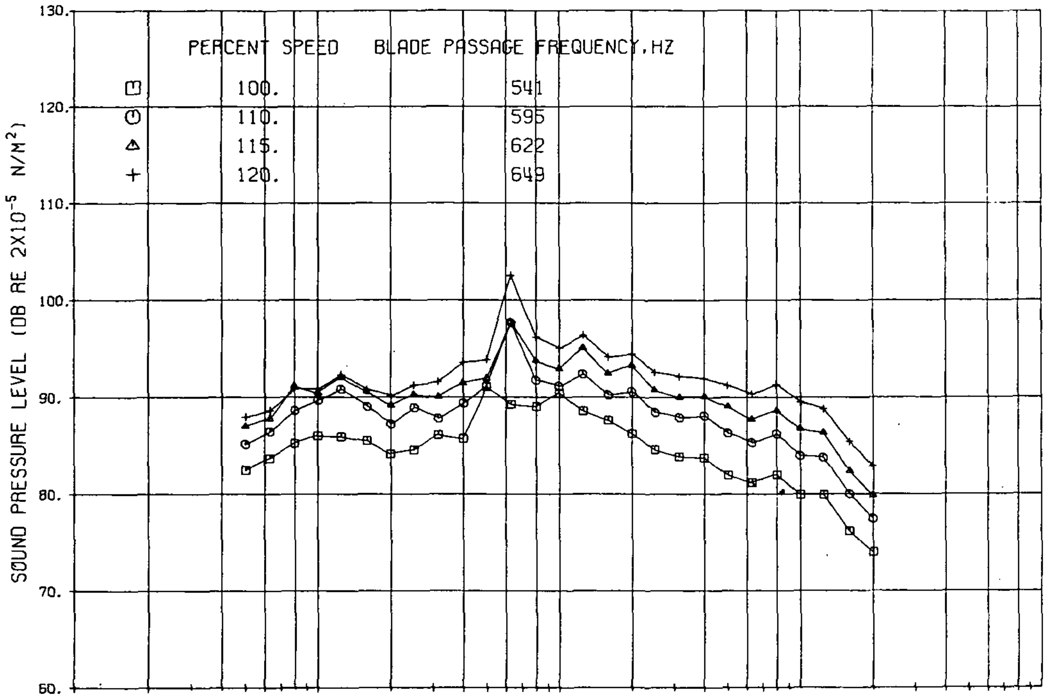


(m) Angle from inlet, 130°.

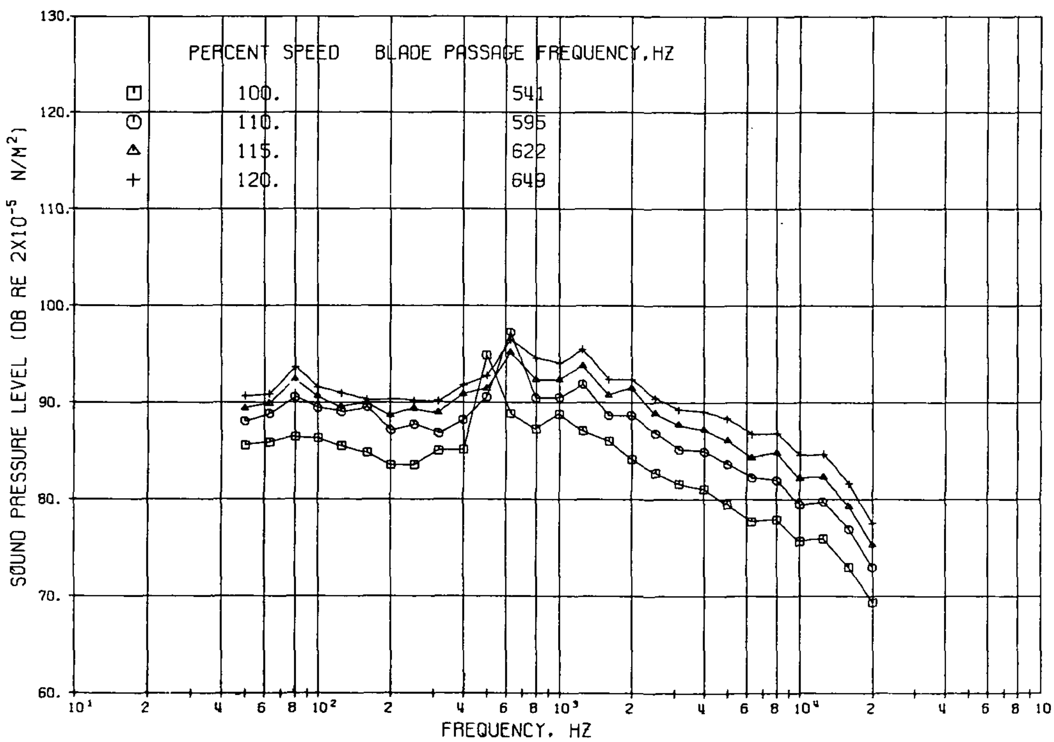


(n) Angle from inlet, 140°.

Figure 26. - Continued.



(o) Angle from inlet, 150°.



(p) Angle from inlet, 160°.

Figure 26. - Concluded.

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